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THE DIE-BACK DISEASE OF CITRUS TREES AND ITS RELATION TO THE SOILS OF WESTERN INDIA

(With examples of successful preventive and remedial treatment)

Part I

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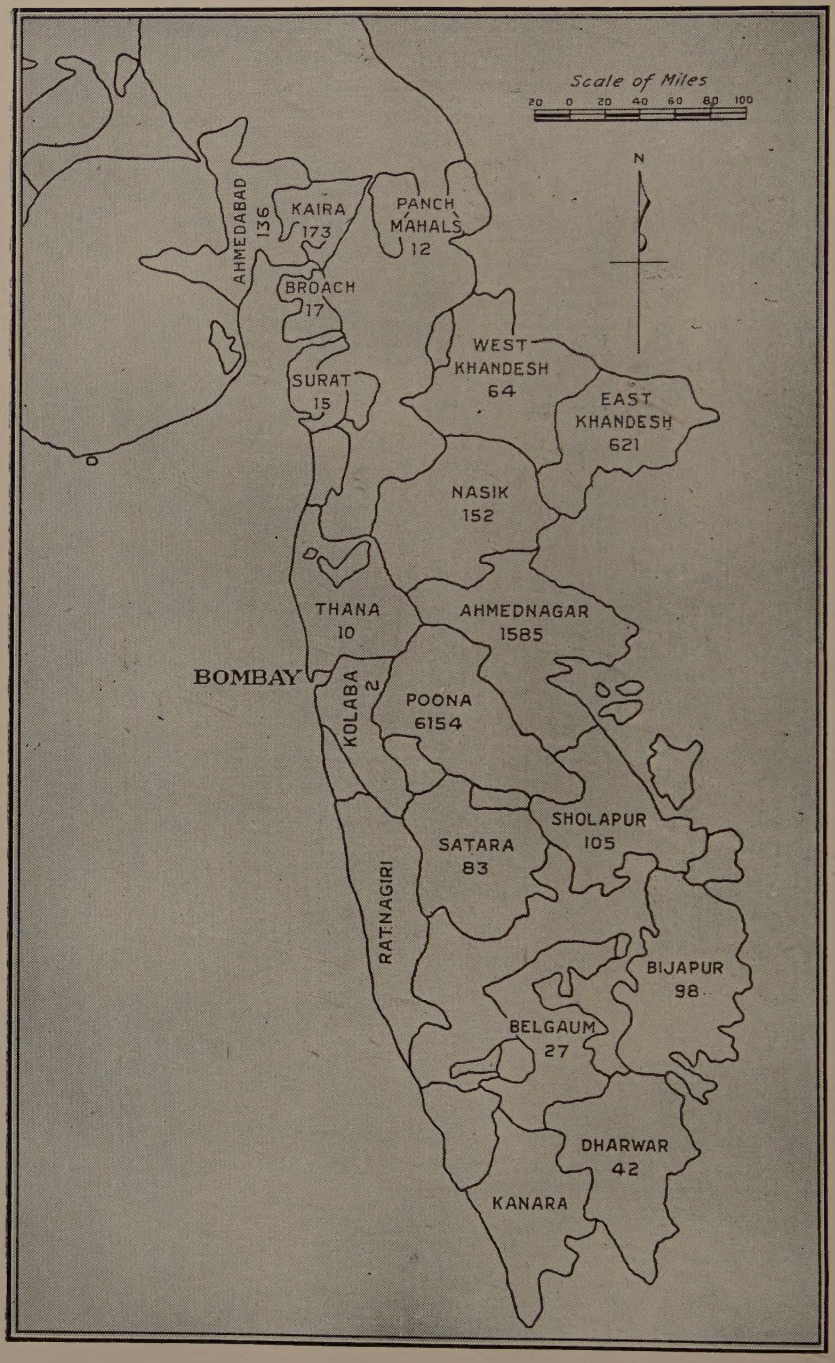

Map of the Bombay Presidency showing distribution of the area under citrus crops. The numbers indicate acreage in each district.

[*Frontispiece*

THE DIE-BACK DISEASE OF CITRUS TREES AND ITS RELATION TO THE SOILS OF WESTERN INDIA

(With examples of successful preventive and remedial treatment)

PART I

CHAPTER I

Introduction

Area under citrus trees in the Bombay Presidency and its distribution.—The citrus trees occupy nearly one-fifth of the total area under fruit cultivation in the Bombay Presidency. In the year 1921-22, the citrus trees covered an area of 9989 acres, out of a total area of fruit crops in the Presidency which came to 49,538 acres. Out of this area, the district of Poona alone has more than 6,000 acres, with about 5,000 acres under Santras (*Citrus aurantium*, loose skinned oranges). The District of Ahmednagar has the next largest cultivation of citrus trees, with an area of 1585 acres. Over a thousand acres of this area are under Mosambis (*Citrus aurantium*, tight skinned oranges). The two Khandesh districts have together 680 acres under citrus cultivation. The other districts of the Presidency have no such intensive cultivation of citrus trees, although every district can boast of having some area devoted to these fruits. (See map attached opposite).

Importance of Die-back.—While there has been a growing tendency among the cultivators to extend the cultivation of citrus fruits, the set-back received on account of one of the most serious diseases of the citrus plant, namely Die-back, is indeed very considerable. As a consequence, the extension of citrus cultivation is very-slow, and in fact, the area brought under cultivation annually hardly makes up for the havoc wrought by Die-back. The disease occurs under varying conditions and in almost all parts of the Presidency. Usually it appears after the first or second bearing of the trees. The terminal branches and leaves turn yellow. Gradually they die. The death of the branches continues downwards. The bearing of the tree is diminished and the whole tree dies in about four years. Nearly all of the varieties of citrus seem to be susceptible to this disease.

The Die-back disease seems to have been prevalent in this Presidency for a long time. Its seriousness was first recognised by the Agricultural Department of Bombay about the year 1912. Certain preliminary trials were made about the year 1921. A study of the disease, a survey of the conditions under which it occurs, and regular experiments to cause the appearance of the disease under controlled conditions were undertaken seriously only during 1924-25. The following pages deal with the work done since then.

History and distribution of the disease outside the Bombay Presidency.—Citrus Die-back is a widely known trouble in all the citrus growing countries of the world. In India this disease has been observed in the Central Provinces from the time of the introduction of the citrus fruits in those parts by Roghoji Bhonsale, in the 18th century. But so far, nothing seems to have been done to combat it. It seems to be prevalent also in Assam in the Khasia Hills (2)*

Floyd (6) states that Die-back of the citrus trees has long been known in Florida. It was first reported by Fowler in 1875. The disease is supposed to have been present in that State since citrus trees were grown under cultivation. Floyd further remarks that the trees growing in the wild are not known to be affected by this disease.

It seems that the disease is considerably prevalent in California, Australia, the Philippines, Dutch Guinea, and Italy.

In 1914, Ross (16) in Australia said that the Die-back disease was not known to exist in Australia. It was first observed there in about 1916.

Previous investigations.—Citrus Die-back was first scientifically studied in Florida by Swingle and Webber (19) in 1892-95. According to them, the disease was not known to exist then outside Florida. In that State Die-back of citrus was very common and its causes were supposed to be improper cultivation and fertilisation, planting on improper soils, growing trees near stables and chicken-runs or on the margins of lakes and marshes.

Since then, a large number of investigators have devoted their attention to this disease. Among them, Floyd and Lipman seem to be prominent in America. Lipman (13) remarks that the peculiar symptoms of the disease may be due to the poor nitrifying power of the soil, with its ammonifying power remaining normal. Floyd believes that the disease is in some way connected with the nature of the organic matter present in the soil. Excessive quantities of organic ammoniates in the soil, a lack of drainage, hard pans near the soil surface, defective cultivation and irregular moisture conditions are all supposed to be the contributing causes of the disease.

Hume (11) in his book on " Citrus Fruits and their Culture " expresses the opinion that Die-back is not a fungus disease, as no spores or threads of fungus are found connected with it as causative agents, that the marks of the disease are an indication of the deranged condition of the whole tree. While supporting Floyd as to the other conditions of the disease, he believes that in each and every case the same causative agent, an enzyme, is at work. The proper pruning of the roots of affected trees frequently brings about a complete recovery of the trees by restoring their balance. All the same, other causes of the disorder should be sought for and removed.

In Australia too similar conditions of soil as reported in America were observed to cause the disease.

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* The numbers in bracket refer to the bibliography given at the end.

Although, therefore, a large amount of investigation has been carried on, and a considerable amount of literature is already published on this subject, the definite cause of Die-back still remains unknown. The physiological nature of the disease, however, seems to be agreed upon, and the remedial measures consist in the complete removal of the conditions causing the disease. The different investigators agree that the curative steps ought to be directed towards proper cultivation, manuring, and drainage of the soil. Excessive applications of organic manures should be avoided. Coit (4) emphasises the proper selection of the land before planting the citrus plants.

Our own experiments during 1921-1923, conducted in co-operation with Professor S. L. Ajrekar, the then Plant Pathologist to the Government of Bombay, have indicated that affected plants revive temporarily by a change of the soil at the feeding roots, and by the addition of brick-bats and stones to the soil to improve its æration. The operation is perhaps very expensive, judging from the temporary relief it gives.

Some work has also been done since then, towards ascertaining whether the disease is due to any fungus, with the help of the Plant Pathology section of the Department of Agriculture of Bombay. Specimens were collected from citrus trees which were severely affected with Die-back, from different localities. No fungoid organism could be detected on the living parts of the branches. The dead parts of the branches showed three organisms which were isolated. These were species of *Diplodia*, *Gloeosporium*, and *Phoma*. Cultures of *Gloeosporium* found on the specimens were prepared in the laboratory. They were inoculated on healthy Mosambi (*Citrus aurantium*, tight skinned oranges) plants, kept in a completely isolated situation. The plants did not manifest any symptoms of Die-back for over four months, when the inoculation was again repeated. No symptom of Die-back is yet observed on these plants, although more than a year and a half has now elapsed. Inoculation trials with the other two species have not yet been made.

Further investigations are, therefore, necessary in the mycological sphere, before a final decision can be arrived at about the cause of Die-back. However, from the observations recorded below, it seems that the soil and climatic conditions are closely associated with the disease. The various investigators mentioned above also seem to support this view. The investigations described in the present paper will therefore be found mainly physiological in nature. In this paper, the conditions under which Die-back occurs in the Bombay Presidency are described. The symptoms of the disease as they appear here have been studied, in detail. The influence of the important soils of this presidency on the performance of citrus plants is also studied, with special reference to the appearance of Die-back. Remedial measures applicable to the various conditions causing the disease, have been tried both in pots as well as in the field. Finally, the possibility of preventing Die-back by using hardy stock plants in raising choice varieties of citrus, is indicated.

Relation of the Environment and the Methods of Cultivation to Die-back in the Bombay Presidency

Before handling the present investigations, a critical study of the conditions, under which citrus trees are grown in the Presidency, was undertaken, with special reference to the extent to which these conditions and the various operations of cultivation as practised at present, contribute to bring about this serious disease of Die-back. It is observed as a result of this study, that almost every citrus growing District has its own peculiarity, both as regards soil and climate, and each citrus variety its own problem.

Soil.—The soils of this Presidency are so varying in nature, that it is practically impossible to classify them correctly under any definite heads and accordingly to describe their nature in general terms. Besides a large number of distinct types of soils, there exist a great variety of shades in what may be called the same kind of soil. The soil varies in character almost from field to field, and many times from plot to plot. The whole soil problem presents a very complicated study. The citrus trees are, however, grown in almost all kinds of soils of this Presidency from a heavy deep black soil to an extremely shallow open soil with little fertility in it. Some of the citrus varieties seem to adapt themselves to soil conditions better than others. In the Poona and the Ahmednagar Districts, there are places with a very deep sticky soil, wherein are cultivated Santras and Mosambis with considerable success. In certain other parts of the Ahmednagar District and in the Dharwar District, are places with shallow stony soils, where also Santras, Mosambis and Kagdi lemons (*Citrus medica*, variety *acida*) are grown. The Pomelos abound in the Konkan tract, where the soil is shallow and open. What is generally named the Shadu soil (a white limy soil, which does not allow the free drainage of water) is common in a number of Districts as a sub-soil, found from one to two feet below the surface, and in certain tracts it is found exposed on the surface, and runs to a great depth. This soil is whitish in colour, sticky in nature, and has a large percentage of lime. At Kolhar, in the Ahmednagar District, an attempt was made by a cultivator to grow some trees of the Santra, Mosambi and the Kagdi lemon varieties in a field where the shadu soil was seen exposed on the surface. The plants never thrived inspite of the best care bestowed on them, and ultimately they all died in less than three years from the time of planting. However, when the shadu soil is a sub-soil, the plants grow very well for a period of four or five years. But when their feeding roots tap the lower shadu layer, the trouble of the plants begins. The same is the case in other parts of the Presidency, where citrus trees are grown in shallow soils, with an underlying layer of some hard substance like stone, through which the roots of the plants cannot penetrate. While planting in such soils, pits of the size of about 3 feet by 3 feet by 3 feet are taken and filled with loose soil mixed with manure. Plants in such pits grow for some time and then suffer from Die-back, when their roots become pot-bound through coming into contact with the surrounding hard layer,

which, it is not possible for them to penetrate. Indian soils in general are deficient in organic contents, and generally wherever this deficiency is not made up by an adequate supply of bulky manures, the citrus trees suffer from Die-back. The supply of manure, however, becomes harmful when it is too freely lavished on plants so as to cause an over-feeding and consequent indigestion. This situation is found in some of the canal irrigated areas and is as harmful as starvation.

Rainfall.—The rainfall in the various parts of this Presidency, is so capricious in nature and distribution, that all the varieties of citrus do not thrive equally well, where other conditions may be favourable. In the coastal tracts, the total annual precipitation goes to so high a figure as 100 inches, but its distribution is restricted to about four months in the year. The other eight months are absolutely dry. The result of such conditions is, that when it rains, it rains incessantly and in torrents, causing continuous stagnation of water at the roots of the trees for a period of four months. This situation is immediately followed by one exactly opposite in nature—a long continued drought for eight months. The soil being unretentive, moisture is not preserved in it to any considerable extent, and even wells do not supply enough water for irrigation. This kind of alternate succession of two opposite extremes year after year, tells very badly on the health of the trees, and they are apt to suffer irrecoverably. In some other tracts, like parts of the Ahmednagar District and the Khandesh Districts, there is always a scarcity of water. The annual rainfall may fall as low as 10 to 15 inches, spread over only three months. The remaining part of the year is dry and wherever canal water is not available, proper cultivation is not possible. The wells are deep and many of them go dry for the greater part of the year ; and during the hot months, it is a serious problem to find water even to keep the citrus trees alive.

Method of Cultivation : *Root exposure.*—The method of cultivation of the citrus trees in this Presidency, has special features. For the first four years from the time of planting, the operations consist of manuring, irrigating, weeding, etc. When the trees reach the age of bearing, they are given rest from growth for a month or two according to the nature of the soil and climate. Irrigation is withheld during this period, and when the trees show drying by shedding their leaves, the soil at their roots is removed in a ring to a distance of about two feet from the trunk of the trees and to a depth of about six inches. This operation exposes a large number of roots. The smaller fibrous roots are all pruned, and after the addition of manure, the roots are covered up again with the original soil after about eight days. This practice of exposing the roots is intended to give an additional stimulus to the trees to put forth blossoms and to check their vegetative growth. Irrigation is then immediately resumed. But it is sparing to begin with and is gradually increased so as to supply the normal quantity of water required, after the first three irrigations. The citrus trees respond to these operations, and the cultivator takes advantage of their nature in so timing his crop as to be able to put it on the market at the most favourable season. This practice,

therefore plays an important part in the economy of citrus cultivation in this Presidency. In its actual practice, however, there is considerable injury caused to the bigger roots of the trees while digging out the soil, and in the way in which the smaller roots are pruned. The cultivator often uses a blunt instrument for this purpose, with the result that the roots are torn and split. Consequently the wounded portions take a long time to heal. Frequently the roots commence rotting. Especially is this so when the roots come in contact with irrigation water which is given not many days after they are severed. This practice, at the same time, gives rise to the alternation of the drought and water-logged conditions described above in a mild form. Exposure of the roots, therefore, adds a potent factor to the list of the factors inimical to the health of plants.

Heavy manuring.—In the canal irrigated areas of the Deccan, there prevails again a practice of very heavily manuring the citrus plantations. The soil in most of the orchards is deep heavy black soil with little through drainage. Irrigation is copious, and the lack of drainage causes stagnation of water at the roots of the trees. Such an over-feeding with both manure and water causes the trees to suffer from Die-back very severely.

Inter-crops.—The practice of taking inter-crops like lucerne and bananas, which require heavy irrigation, and which continue to occupy the land for a considerable time, prevails in the case of Loni in the Poona District, and some places in the Khandesh Districts. Such conditions bring about the most uncongenial atmosphere for the growth of citrus trees. In consequence, the citrus trees suffer seriously from an excess of water, in their early stages of growth. The land can never become dry on account of the inter-crops. The situation is further aggravated if the soil happens to be heavy, as it certainly is in many cases. The inter-crops are not usually taken after the trees commence to bear.

At Rahuri in the Ahmednagar District Santra and Mosambi gardens are seen in good health. They are situated in deep alluvial soil on the banks of the river Mula. The river bed is about eight feet below the level of the gardens. The river goes dry for a great part of the year. The gardens, therefore, have an excellent natural facility for drainage. This is practically the only place in the Presidency, where citrus trees are seen to fare well for a number of years.

The foregoing are some of the important aspects of the conditions under which citrus trees are grown in this Presidency. These factors bring about the bad health of the trees, singly or in combination. The trees, therefore, are seen to suffer from Die-back almost in all the citrus growing centres of the Presidency. The seriousness of the trouble is enhanced when several factors are concurrent. Die-back is thus observed in almost every citrus orchard. The gardens which are free from the attack of this malady form only rare exceptions. The aggregate damage caused by Die-back is enormous.

Susceptibility of the Different varieties of citrus trees to Die-back

All the citrus types do not seem to be susceptible to Die-back to the same extent. Their relative susceptibility under exactly similar conditions of soil, water, climate and treatment can be gauged from the following data, collected from the gardens of leading cultivators, in the various citrus growing districts of this Presidency. The stock used was *Jamburi* (*C. Medica*, variety *limonum*) for all the varieties in all the cases cited.

The Poona District.—(*a*) The garden of Mr. Mandre at Phursangi is situated in the sugarcane area and is irrigated by canal water. The soil of this garden is a heavy deep black soil, with bad drainage. The plantation is twenty-five years old. It gives the following figures :—

Table No. 1.

Serial No.	Name of variety	Original number of trees	Number of trees succumbed to Die-back	Number of trees affected but living in 1927
1	Santra	250	151	99
2	Mosambi	620	*Nil.*	620
3	Id*	12	*Nil.*	All these trees are affected to a lesser degree than Mosambis.
4	Jamburi* ..	1	*Nil.*	This tree is not affected as much as Id.
5	Pomelo† ..	14	*Nil.*	These are practically unaffected.
6	Mahalung‡ ..	2	*Nil.*	These are absolutely unaffected.

(*b*) In one of the gardens belonging to Mr. Gomaji Patil of Loni Kalbhor, the different varieties of citrus trees manifested the severity of attack by Die-back under uniform conditions, as follows : (This plantation is 15 years old).

Table No. 2.

Serial No.	Name of variety	Original number of trees	Number of trees succumbed to Die-back	Number of trees affected but living
1	Santra	6	*Nil.*	6, These trees are very badly affected.
2	Mosambi	540	100	440
3	Sakhar limbu§ ..	2	*Nil.*	2, These trees are healthy.
4	Pomelo †	4	*Nil.*	4, These trees are healthy.

* *Id* and *Jamburi* are both varieties of *Citrus medica* variety *limonum*.
† *Pomelo* is *Citrus decumana*.
‡ *Mahalung* is *C. medica* proper.
§ *Sakhar limbu* is *Citrus medica* variety *limmetum*.

West Khandesh District.—A garden at Dhulia, belonging to Mr. Baburao Ransingh, pleader, has heavy black soil, three feet in depth, with murum below. A well irrigates the garden. The plantation is only ten years old. The attack of Die-back on the various varieties of citrus, all reared on Jamburi stock, is as follows :—

TABLE No. 3.

Serial No.	Name of variety	Original number of trees	Number of trees succumbed to the disease	Number of trees affected but living
1	Santra	300	*Nil.*	100 trees are affected. The other 200 trees are healthy.
2	Mosambi	32	*Nil.*	All these are healthy.
3	Kagdi lemon ..	30	*Nil.*	All these are healthy.
4	Mahalung ..	5	*Nil.*	These trees are particularly healthy.

Ahmednagar District.—At Kolhar, in the garden belonging to Mr. Govindrao Kulkarni, the following data were collected. The soil of this garden is a heavy deep black soil, with sugarcane cultivation all around. Irrigation is received from the canal and is very copious. The plantation is eleven years old.

TABLE No. 4.

Serial No.	Name of variety	Original number of trees	Number of trees succumbed to Die-back	Number of trees affected but living
1	Santra	25	*Nil.*	Very badly affected.
2	Mosambi	250	*Nil.*	Affected.
3	Jamburi	2	*Nil.*	Healthy.

From the above tables it will be seen that there is a vast difference in the degree of susceptibility of the various citrus varieties to Die-back. The Santras (*Citrus aurantium*, loose skinned oranges) are the most susceptible. Mosambis (*Citrus aurantium*, tight skinned oranges) come next. The Id and the Jamburi (*Citrus medica* variety *limonum*) Kagdi lemon (*Citrus medica* variety *acida*), Pomelos (*Citrus decumana*), and Mahalung (*Citrus medica* proper), all resist the disease to a great extent. Mahalung is perhaps the most resistant variety. The field conditions under which their roots fed were uniform. These observations, therefore, seem to indicate that the Santra is most susceptible to Die-back.

The important fact may here be noted that the different varieties of citrus manifest different degrees of susceptibility to Die-back, even when they are all raised on the same kind of stock, namely, Jamburi. This opens up a new field of study, which remains to be explored.

Plate No. 1. A typical Die-back affected Mosambi orchard. [*To face page 9*

Symptoms of Die-back as observed in the Bombay Presidency.

The symptoms of Die-back have peculiar characteristics of their own. Whole plantations, individual trees or trees in patches may be affected. The disease usually makes its appearance after the first or second bearing. Younger trees are also affected under extreme conditions. The first symptoms appear when the terminal leaves and shoots turn yellow. This yellowing due to Die-back is different from simple mottling or the yellowing of ripe leaves. The symptom appears all at once in the new shoots of a fresh flush. The tree may be apparently in perfect health, before the flush which makes the disease apparent. What happens is that the new sprouts with pale tender leaves do not mature at all. They do not develop the normal green colour. After a time they attain a considerable turgidity, but remain stunted and pale. Many a time variegated leaves are also observed. The variegation is caused by regular stripes of green and yellow colour, alternating one another. The green stripes are mostly seen alongside the main veins, indicating a collection of chlorophyll matter on either side of such veins. The yellow stripes are deficient in chlorophyll grains. It is not always all the new sprouts of one particular flush on a tree, that exhibit this symptom. The new sprouts arising on one or more main branches only may behave so. In a subsequent flush more branches will be attacked, while those that are already attacked get worse. Again, when the symptoms appear, it is seen not on one or two or a few individual fresh sprouts in a sporadic manner, but on all the new sprouts on a main branch. The unit of attack is, therefore, a main branch of a tree and not an individual sprout or two. From the time the first attack is seen, it may take from one to two years before the whole tree is seen to suffer. This is why in the earlier stages of the trouble, it is seen on some parts of trees only, while the others remain apparently healthy. The further symtoms are the death of the yellow shoots and leaves, extending gradually to the lower parts, with a diminution in the bearing capacity of the affected tree. Fresh growth on an affected branch is very sparing, and new sprouts never develop normally either in colour or in vigour. The range on the tree in which new sprouts appear is pushed downwards as it were, and dormant buds on the thicker stems just below the dead parts come into activity. In a tree very much advanced in the disease, it is only the basal stumps of the main branches which survive, with a few undeveloped yellow multiple sprouts on them. At this stage, which is reached in about four years from the time the first attack is seen, the tree cannot bear even a single fruit and it dies soon after. The formation of gum pockets and dark excrescences as described by Floyd (6) in America, is not seen under the conditions of the Bombay Presidency. While these are the prominently visible symptoms of Die-back, a detailed examination reveals the fact that every part of the affected tree displays a characteristically deteriorated condition of health.

It will perhaps be proper here to distinguish Die-back from certain other similar diseases like Wither-tip, Anthracnose, and Citrus Blight. These latter diseases also affect the twigs and leaves of citrus trees, but

they are mostly confined to the tender terminal parts only. In the case of Wither-tip, the tips of branches dry, their leaves are shed, and the symptoms are easily mistaken for those of Die-back at least in the earlier stages. In Wither-tip the death of the branches does not continue downwards to affect the thicker stems. The absence of multiple sprouts is characteristic of this disease which is said to be caused by an organism, *Colletotrichum gloeosporioides*. Anthracnose is easily distinguished from Die-back by the presence of brownish patches on the tender sprouts at a short distance from their tips. There is a constriction on their stem where these patches are seen. The parts above the constriction wilt and hang down. Anthracnose is also said to be caused by an organism of the genus *Gloeosporium* or *Colletotrichum*. In Citrus Blight, the branches wilt either gradually or suddenly. A number of water sprouts are seen on the lower thicker stems, and the affected trees may produce profuse blossoms out of season, the setting of fruits being very poor. Citrus Blast is said to involve mostly the petioles of the leaves and is caused by a bacterium (5). So far as our present knowledge of citrus Die-back goes, it is not known to be associated with any organism as its causative agent.

Further details of the symptoms of Die-back as they occur in the Bombay Presidency are given below :—

Detailed Studies of Diseased Plants.

Roots.—Under dry conditions of soil, the roots of citrus trees affected by Die-back become dry and shrivelled and ultimately die off. The fibrous roots are not well formed ; that is to say, the formation of brooms at the cut-ends is scanty. Fibrous roots are the first to die under conditions which develop the disease. Wherever the soil is extremely heavy, and the deeper layers are hard for penetration, the roots are seen to crowd in the top layer of soil of not more than a foot in thickness, and only a few roots are seen at a depth of two feet from the surface. The topmost layer of soil being friable under almost all dry conditions, gives the roots a better opportunity for growth. Even for a well-grown tree of about fifteen years of age, it is only the tap root and a few thicker roots that penetrate to a depth of more than two feet in the case of a deep heavy black soil. The same is the case with the roots under conditions of scarcity of water, though for a widely different reason. Where irrigation water is not enough, it is only the upper-most layer of soil which gets wet at each turn of irrigation, and the lower layers always remain dry. The roots naturally crowd in the wet layer of soil, which is shallow, and during the hot parts of the year, when even the usual small quantity of water may become unavailable, they dry and the trees suffer severely. Such conditions prevail in parts of the rainless district of Ahmednagar.

The penetration of roots into the soil layers under these conditions is shown by the following figures. Long trenches, three feet in depth, were dug at a distance of three feet from the trunk of the trees. They were Mosambi trees (*Citrus aurantium*, tight skinned oranges), twelve years of age. A counting of the number of roots in the various soil layers was recorded. The trees were affected with Die-back to a great extent. The figures were as follows :—

TABLE No. 5.

Layer of soil examined	Area in square feet	Number of roots found
1. Up to one foot in depth from surface.	115	847
2. From one to two feet in depth.	115	88

Where roots are badly injured during the course of root exposure, and are allowed to remain in the soil as they are, the wounds are not properly healed. The injured roots rot at the wounds. Rotting progresses upwards to affect the upper healthy parts also. Specially so is this the case in the presence of moisture. The bark rots first. When pressed with the fingers, a watery sticky substance is seen to come out of it. With a slightly greater pressure, the bark easily detaches itself from the wood. Where rotting has sufficiently advanced, the bark is easily separated from the wood. Part of the wood is also gradually affected. A transverse cut of such roots shows a blackening of the interior of the wood to a considerable distance above the wounded portion. On such roots subsidiary and fibrous roots are almost absent. They are, therefore, almost functionless. They only form a diseased limb of the tree and seriously stand in the way of its good health.

Under the microscope, there does not seem to be any clear distinction between the roots of healthy and affected trees, under dry conditions of soil. Roots of uniform thickness of 2mm. in diameter were examined in the case of a badly affected Santra plant, and compared with similar roots of a healthy plant growing in the same garden. They did not show any difference in their structure.

Where stagnation of water in the soil is associated with Die-back, it is observed that the roots swell and rot. Their blackened barks are easily sloughed off by a little pressure of the fingers. The rotten portion gives an offensive smell, as of putrification. The fibrous roots mostly disappear in the soil. The suffering of the trees is most acute and their death is rapid in such cases.

Branches : Length of the branches.—The branches of the citrus trees affected with Die-back do not attain their full development, and remain light yellowish in colour. The sprouts put forth in flushes subsequent to the appearance of the disease, are much stunted in growth, as will be evident from the figures given in the following table.

Table No. 6.

Statement showing the length of the sprouts of Santra plants before and after Die-back appears.

Nature of sprouts	Total No. of sprouts measured	Percentage of sprouts with a length of						
		Below 5 cms.	6-10 cms.	11-15 cms.	16-20 cms.	21-25 cms.	26-30 cms.	above 30 cms
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
1. Healthy sprouts.	370	52	19	10	5	5	3	6
2. Affected sprouts.	525	79	16	4	1	*Nil.*	*Nil.*	*Nil.*

Note.—The data of the above table are graphically represented in Figure No. 1.

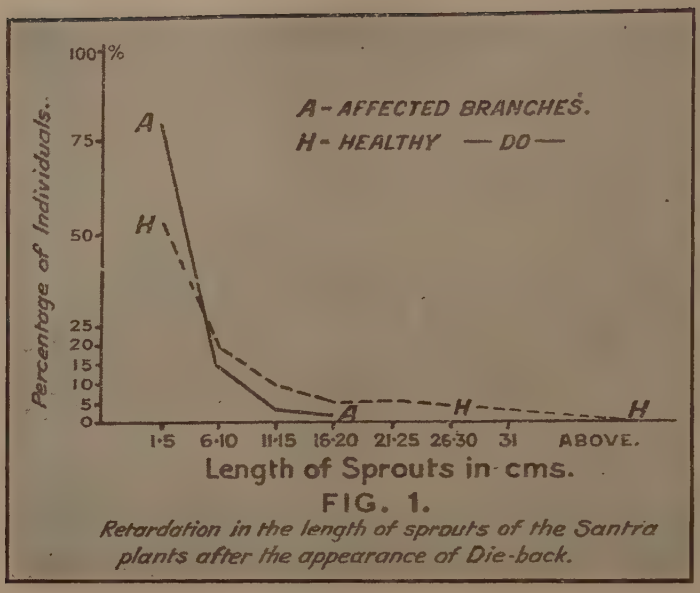

FIG. 1.

Retardation in the length of sprouts of the Santra plants after the appearance of Die-back.

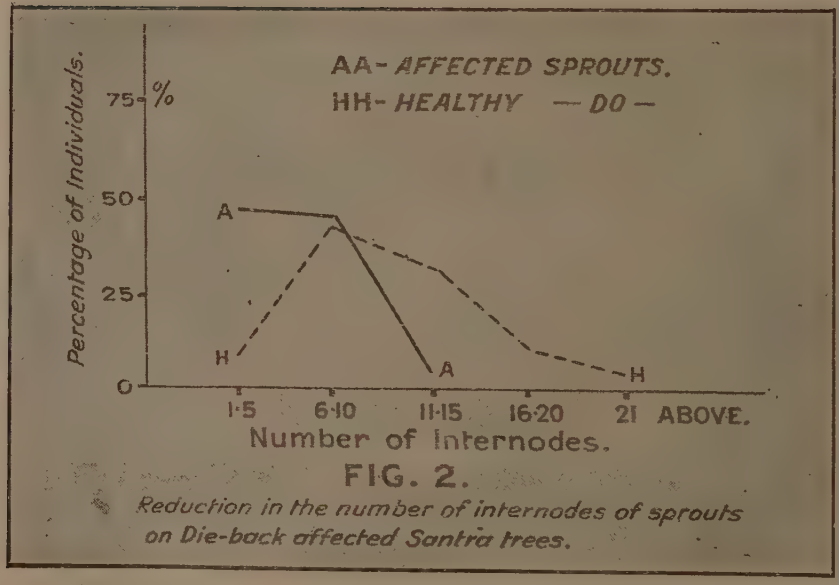

FIG. 2.

Reduction in the number of internodes of sprouts on Die-back affected Santra trees.

These figures indicate that the whole range of length of the sprouts is greatly lowered when Die-back sets in. Affected sprouts rarely attain a length of 20 cms. or more, while 79 per cent. of them are below 5 cms. in length. In the healthy sprouts a percentage so high as 35 falls between 5 cms. and 20 cms. and 14 per cent. of the sprouts have a length of over 20 cms.

Further, the number of leaves, or rather inter-nodes on each sprout, is reduced, but not proportionately to the reduction in length. This means that a comparatively larger number of inter-nodes is accommodated within the same length, and the whole sprout looks compact and "bushy". This will be clear from the following data :—

TABLE No. 7.

Statement showing the number of Inter-nodes on Santra sprouts before and after Die-back appears.

Nature of sprouts	Total No. of sprouts examined	Percentage of sprouts with				
		1-5 internodes	6-10 internodes	11-15 internodes	16-20 internodes	21-30 internodes
		per cent.	per cent.	per cent.	per cent.	per cent.
1. Healthy sprouts.	263	8	43	33	11	4
2. Affected sprouts.	362	48	46	6	*Nil.*	*Nil.*

Note.—See Figure No. 2.

Here too the range is lowered after the appearance of Die-back. Ninety-four per cent. of the affected sprouts have less than ten internodes, whereas only 51 per cent. of them are found in the healthy sprouts. The percentage of affected sprouts with more than ten internodes is as low as only 6, while in healthy sprouts the same goes as high as 48.

TABLE No. 8.

Nature of trees from which specimens were examined	Nature of branches examined	Percentage of the breadth of each tissue calculated on the total diameter of transverse section						Total diameter of section
		Epidermis	Chlorophyll	Phloem	Cambium	Xylem	Pith	
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	μ
1. Partly affected tree, with both healthy and affected branches. Branches were taken from one and the same tree.	*Healthy*: 2 mm. in diameter.	1·42	10·04	4·6	8·0	24·28	38·4	2,279·20
	Affected: 2 mm. in diameter.	2·60	10·96	4·8	10·4	20·12	37·6	2,234·4
2. In very good health.	*Healthy*: 2 mm. in diameter.	1·68	9·96	5·30	7·88	33·40	32·02	2,233·60
3. Severely affected by Die-back.	*Affected*: 2 mm. in diameter.	2·36	8·28	3·70	13·00	24·28	28·94	2,161·60

Note.—Every figure in this table is an average of 20 readings. The branches taken were of one and the same season's growth, in all cases.
The microscope used was No. 23769, 4×⅔ (Watson and Sons, Ltd).

While studying these symptoms of Die-back it was suspected that there might be a diminution in the size of the branches even before the disease is actually seen. A number of measurements of individual branches were accordingly recorded but there appears to be no diminution in the development of the individual branches in the pre-disease period of growth.

Internal structure of branches.—There seemed to exist considerable differences between the dimensions of the tissues of healthy and affected branches. Measurements were, therefore, recorded of such dimensions. Table No. 8 gives the comparative percentage figures, calculated on the total diameter of the transverse section.

The absolute values of the total diameter of the section are given in the last column of table No. 8. The difference in the total diameter is very slight in the sets which are to be compared. This indicates the uniformity of branches selected. The sum of the percentage of the different tissues does not make 100, because the cortex region is nowhere completely measured.

If we consider the different tissues one by one we find that the affected branches have a thicker epidermis than the healthy ones. When branches were selected from the same tree, the breadth of the epidermal region of healthy branches was 1·42 per cent. of the total diameter of the sections. It was 2·60 per cent. in the affected branches. That is, the increase in the epidermal region is of about 85 per cent. In the second set, where branches came from different trees, the healthy and affected branches show epidermal layers of 1·68 per cent. and 2·36 per cent. respectively. The increase here is, therefore, of about 42·0 per cent. Branches affected with Die-back seem to develop a thicker epidermis.

In the first set of branches, there does not exist any great difference in the area in which the chlorophyll grains are scattered. An examination of the sections of fresh branches, however, clearly shows that in the healthy ones, the chlorophyll grains are much more thickly placed than in the affected ones. The difference is somewhat more marked, where branches were taken from different trees. In the affected branches, not only are the chlorophyll grains very thinly scattered, but even the area in which they are scattered is reduced and pushed towards the epidermis. The reduction is of about 20 per cent. Therefore, the chlorophyll material is markedly deficient in Die-back affected branches. This is why they look yellowish and pale.

Branches taken from the same tree do not show much difference in the development of the phlœm bundles. Those taken from the different trees show a marked difference. The phlœm bundles are reduced in size by about 30 per cent. in the affected branches. This perhaps indicates a smaller quantity of prepared food conducted from the leaves.

Next comes the cambial region. In branches taken from the same trees, the cambial region shows an increase by about 25 per cent in the affected branches. In those taken from different trees, it increases by about 65 per cent. The cells are badly deranged and their walls look fused. They are all more or less blackened. As the Cambium is the actively growing tissue of the branches an increase in the cambial region means an increase in its activity, which may normally mean vigorous a growth of the branches.

The xylem bundles of healthy and affected branches have a breadth of 24·28 per cent. and 20·12 per cent. respectively in one set, while they have a breadth of 33·40 per cent. and 24·28 per cent. respectively in the other set. The reduction in the size of the xylem bundles of the affected branches is, therefore, from 16 per cent. to about 30 per cent. As the xylem bundles carry the raw sap to the leaves, a reduction in their size indicates a poor flow of the raw sap upwards to the leaves. The observations described under roots corroborate this, which results in reduced absorption.

The pith of the branches does not show any very great variation.

Taking the whole structure of the branches into consideration, it is clear that the cambial region is disproportionately wide. Not only are the cambium cells affected, but also the secondary xylem and the secondary phlœm which are young, tender and more active, and which lie nearest to the cambium layers on either side, seem to suffer. The disintegration and fusion of the walls of the cambium cells appears to spread on both sides. The most important and active tissues are thus severely affected when Die-back appears.

With a smaller amount of chlorophyll both in the stem and in the leaves (see under leaves), a reduction in the amount of raw sap taken in and a consequent want of sufficient prepared food, and the disturbance in the activity of the growing tissues, the branches commence to die gradually. The younger terminal and subterminal shoots die first. Then the lower thicker stems follow. A limited number of the smaller branches are seen to die every year even in healthy Santra trees. The death of some of the weaker branches, especially of those that are located inside the crown of the trees and hence do not receive a sufficient amount of light and ventilation, seems to be a normal phenomenon. A number of the smaller branches also die as a result of the artificial rest given

to the trees to force a blossoming. The owner of the Santra orchard knows very well that such dead branches have to be pruned every year to keep the trees clean. He does it as a matter of course. When trees are in sound health, the number of branches which thus die annually comes to about ten per cent. of the total number. The living and dead branches of 25 healthy Santra trees were counted just before the annual cleaning operation of the trees. The average of the living and dead branches per tree came to 4,104 and 395 respectively. This loss of branches is more than made up by new flushes season after season. The trees in health, therefore, grow and produce fruits. But when Die-back appears, the death of the branches is very rapid. The vigour of the trees is checked. They produce new sprouts. The death of the existing sprouts progresses fast. The trees are reduced in size and they die ultimately.

A periodical record of the living and dead branches of four Die-back affected Santra trees was maintained. The trees were all five years of age. They were all in one and the same garden, in heavy deep black soil. Table No. 9 gives the details of this. After each counting, all the dead branches were pruned in all cases. When after about six months, the branches were again counted, there were always new branches which had died in the interval. It was further noticed that some of the dead branches dropped off naturally. There were also new sprouts put forth by the trees during the flushing seasons.

TABLE No. 9.

No. of trees	Number of branches					
	February 1927		August 1927		December 1927	
	Living	Dead	Living	Dead	Living	Dead
No. 109 ..	3,180	410	5,168	823	4,067	2,829
No. 110 ..	537	560	..	..	407	1,247
No. 111 ..	..	..	743	1,900	123	490
No. 112 ..	..	..	2,400	588	1,851	912

Note.—Tree No. 109 was affected by Die-back from February 1927.
Tree No. 110 was already considerably affected in February 1927.
Tree No. 111 had the first appearance of Die-back in 1925.
Tree No. 112 got the first attack in June 1927.

The total number of branches on any tree does not remain the same in all the seasons. All the same, the percentage of dead branches increases enormously at each counting. The death of the branches is much accelerated by the progress of the disease. This fact is concisely expressed in table No. 10.

TABLE No. 10.

	Die-back just set in	After 6 months	After 12 months	After 18 months	After 24 months	After 30 months	After 36 months
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Percentage of dead branches.	11–19	14–33	41	51	..	72–75	80

As Die-back progresses the total number of branches on the affected trees goes on diminishing. The number of dead branches increases, and that of the living ones decreases. In about three to four years, affected trees are nearly dead. Their basal stumps alone remain to completely die in about a year more.

Multiple sprouts.—The death of the branches is gradual, and while it progresses, the tree puts forth new sprouts immediately below the dead portion. The buds on the

thicker stems, which were till now dormant, come to activity. Frequently more than one sprout is seen to spring up from one and the same leaf-axil. These sprouts do not fully develop, nor do all of them attain equal lengths. Their leaves are pale yellow or whitish yellow. Gradually death attacks them too. In this way, the whole tree succumbs in course of time.

A counting of these multiple sprouts was done and the following table deals with its details. In healthy trees, sometimes two sprouts are seen to spring up from one and the same leaf-axil, and rarely three. All these sprouts develop normally, and are more or less equally vigorous. When the multiple sprouts are induced by Die-back, many buds give rise to three or even more sprouts. The following table explains this statement. (See Plate No. 2).

Table No. 11.

Statement showing the number of sprouts arising from one and the same bud before and after Die-back appears

Nature of tree	Total No. of buds examined	Percentage of buds giving rise to				
		1 sprout	2 sprouts	3 sprouts	4 sprouts	5 sprouts
1. Healthy tree.	1,200	per cent. 97	per cent. 3	per cent. *Nil.*	per cent. *Nil.*	per cent. *Nil.*
2. Affected tree.	1,320	36	32	21	8	3

Note.—See Figure No. 3.
The table explains itself.

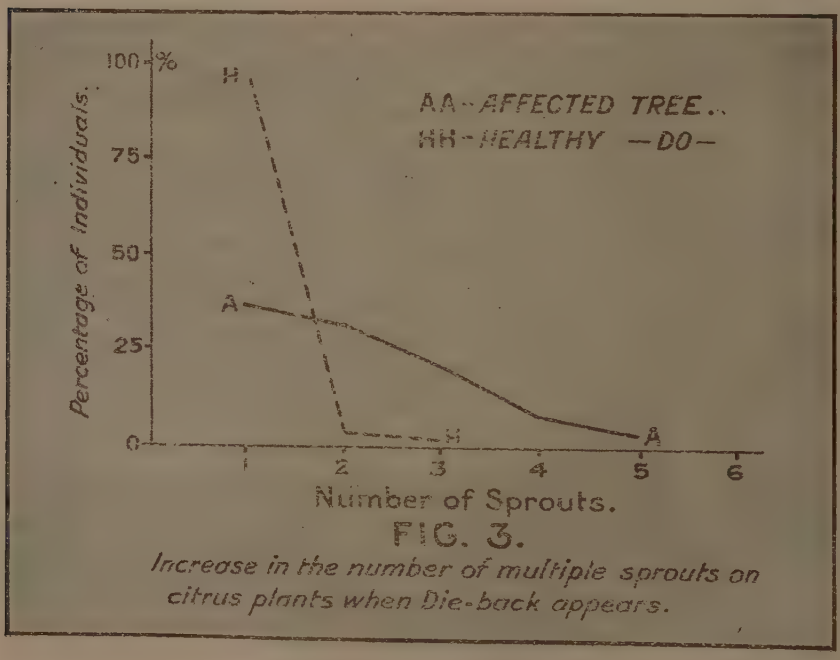

FIG. 3.

Increase in the number of multiple sprouts on citrus plants when Die-back appears.

Plate No. 2.

Multiple sprouts rising from the dormant buds on a thick stem of a Die-back affected Mosambi tree, just below the dead portion.

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S-shaped Branches.—Sometimes in the early stages of the disease, dormant buds on the lower thicker stems come into activity as explained elsewhere, and produce highly elongated sprouts. These sprouts resemble water-sprouts in all points, except that they continue to grow in length for a large number of days. After reaching a certain length they bend under their own weight, and their tips point downwards. Later, the tips take an upward turn, giving the whole branch an S-shaped form. B. F. Floyd (6) includes the appearance of such branches among the secondary symptoms of the disease. These S-shaped branches are seen to rise from the lowest parts of the thicker stems of affected trees. Their leaves are not distinctly yellowed. They sometimes extend in length to more than three feet, with a girth at the base of not more than about 3 cms. S-shaped branches of smaller dimensions can be found scattered among the normal branches. These are, however, of rare occurrence under our conditions.

Leaves.—The change in the colour of the leaves of trees when Die-back sets in, has already been described. Then the size of the leaves and their shape also undergo considerable change. The leaves are much reduced in size and hence in surface. Their shape changes to narrow and longish from broad and proportionate. A study of these points is represented as follows:—

Table No. 12

Statement showing the length of Santra leaves before and after Die-back appears

Nature of leaves	Total No. of leaves measured	Percentage of leaves with a length of				
		1 cm.	2 cms.	3 cms.	4 cms.	5 cms.
		per cent.	per cent.	per cent.	per cent.	per cent.
1. Healthy leaves	210	*Nil.*	*Nil.*	3	9	9
2. Affected leaves	198	6	20	29	26	17

Nature of leaves	6 cms.	7 cms.	8 cms.	9 cms.
	per cent.	per cent.	per cent.	per cent.
1. Healthy leaves	27	26	22	4
2. Affected leaves	2	....	....	....

Note.—See Figure No. 4.

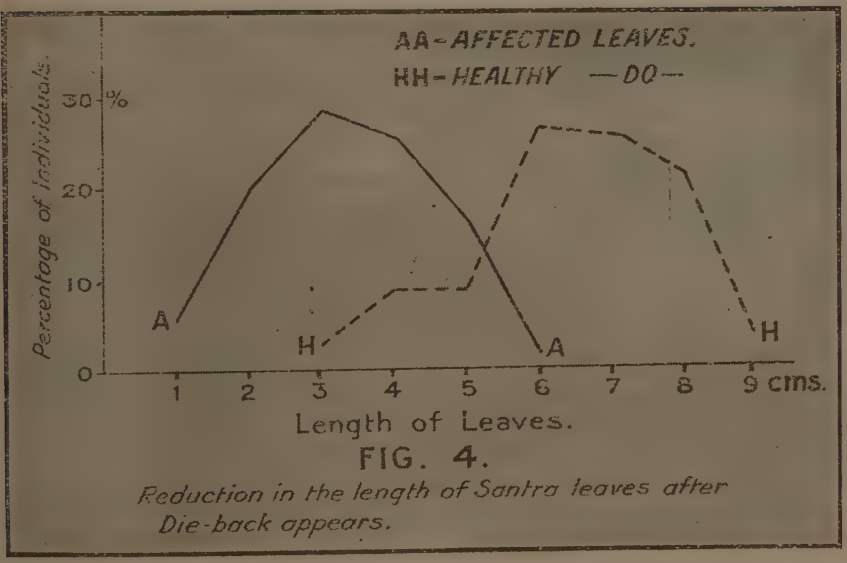

FIG. 4.

Reduction in the length of Santra leaves after Die-back appears.

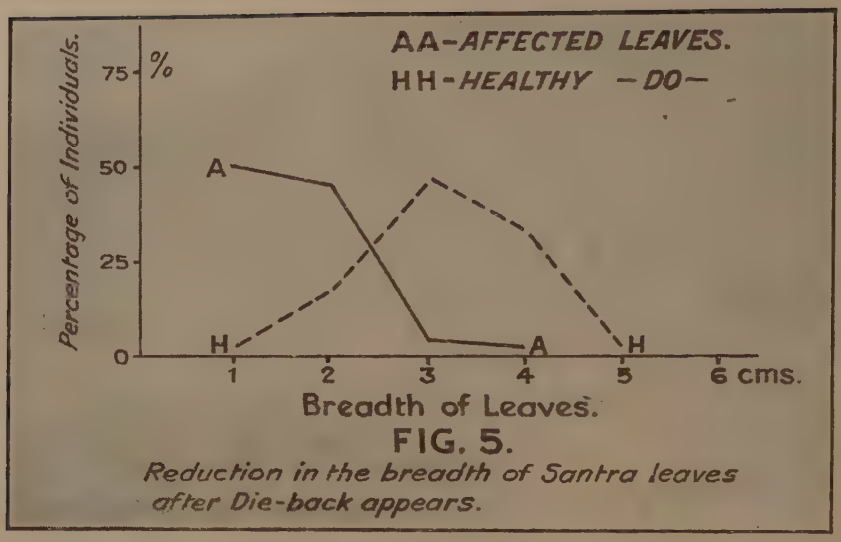

FIG. 5.

Reduction in the breadth of Santra leaves after Die-back appears.

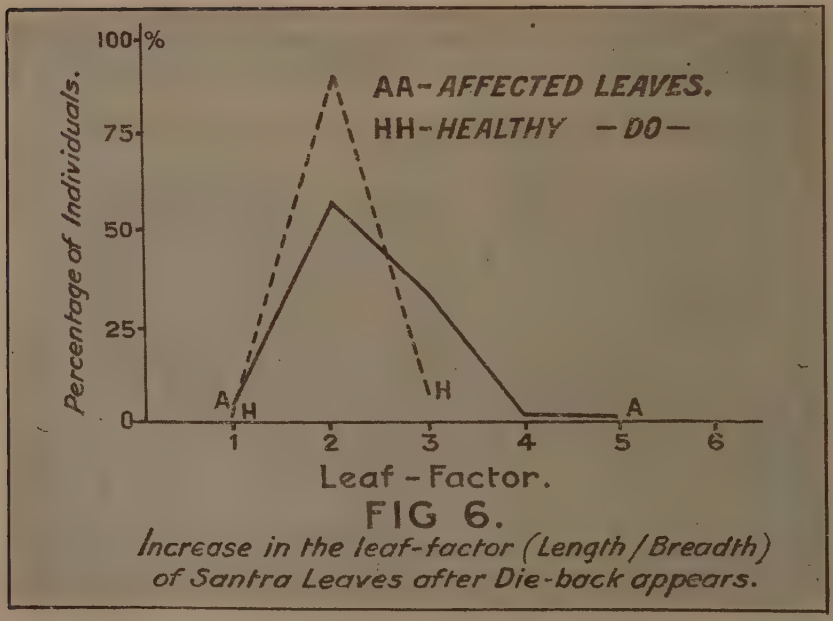

FIG 6.

Increase in the leaf-factor (Length/Breadth) of Santra Leaves after Die-back appears.

It will be seen from the above table, that the whole range of the length of the leaves is shifted downwards, without much alteration in the frequencies. The length of the leaves is reduced to half.

The reduction is more marked in the breadth of the leaves than in their length, as can be seen from the following table :—

Table No. 13

Statement showing the Reduction in the Breadth of Santra Leaves after Die-back appears

Nature of leaves	Total number of leaves examined	Percentage of leaves with a breadth of				
		1 cm.	2 cms	3 cms.	4 cms.	5 cms.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Healthy leaves	210	2	17	46	33	2
2. Affected leaves	198	50	44	4	1	Nil

Note.—See Figure No. 5.

It is interesting to note that in the healthy leaves, about 19 per cent. only have a breadth of 2 cms. or less, and the remaining 81 per cent. have a breadth of 3 cms. or more. In the affected leaves, so many as 94 per cent. have a breadth of 2 cms. or less, whereas leaves with a breadth of more than 2 cms. show a meagre percentage of five only. The breadth of the leaves is reduced, in general, to almost one-third.

It is evident, then, that when the breadth of the leaves undergoes a larger percentage of reduction than does the length, the leaves should look narrower and longer, though smaller, than usual. This point is also brought out by the leaf-factor, or the length of the leaves divided by their breadth. A comparatively longish leaf has a greater leaf-factor :—

Table No. 14

Nature of leaves	Total number of leaves examined	Percentage of leaves with a leaf-factor of				
		1	2	3	4	5
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Healthy leaves	210	2	89	9	Nil	Nil
2. Affected leaves	198	5	56	34	3	1

Note.—See Figure No. 6.

Now we see that 89 per cent. of the healthy leaves have a leaf-factor of 2, and only 9 per cent. have a leaf-factor of 3, and none at all of more than 3. In the affected leaves, only 56 per cent. have a leaf-factor of 2, and 38 per cent. have a factor of 3 or more. The range is one to three in the healthy leaves, while in the affected it is from one to five, that is, it is nearly twice as wide in the affected ones as in the healthy leaves.

Internal structure.—When examined under the microscope, the affected leaves show a striking want of chlorophyll grains. Most of the palisade cells even are almost empty. The few sparcely scattered chlorophyll grains are found immediately below the upper epidermis. In sections of variegated leaves, the chlorophyll grains are seen grouped near the cut veins. The whole chlorophyll region is shifted up towards the upper epidermis. In the case of healthy leaves the palisade cells as well as one or two rows of the spongy paranchyma, which lie just below them, are seen full of deep green chlorophyll matter. The chlorophyll grains are seen even in the lower cells almost up to the lower epidermis. A measurement of the chlorophyll area of healthy and affected leaves is given in table No. 15.

Table No. 15

Nature of leaves	Total thickness of leaves	Area covered by chlorophyll	Remarks
	μ	μ	
Healthy ..	271·66	94·71*	* This area includes only the region where chlorophyll grains are thick.
Affected ..	271·66	45·69	

Note.—The figures are the averages of twenty readings. The number of the microscope and the magnification are No. 194099, 3 × ⅓, made for Baird and Tatlock, Ltd., London.

Beyond the reduction of chlorophyll grains the inner structure of Die-back affected leaves does not show any derangement of tissues. Even the total thickness of such leaves is the same as that of normal healthy leaves. But the want of chlorophyll grains indicates that a sufficient quantity of food is not prepared in the leaves.

Fruit.—The bearing of Die-back affected trees is far from being profuse. The small number of fruits that are set, are stained brownish in spots of the size of a pea, and many of them drop while under-developed. The few that are then left develop a warty skin. The juice sacks inside such fruits are dry, and if any juice is found at all, it is insipid. The fruits are absolutely useless. (See plate 3.)

Summary.—As soon as the roots shrivel and the fibrous roots are reduced in number, Die-back is seen to appear on the branches. The roots may disappear under dry conditions and may rot under conditions of stagnation of water. The disease appears in a new flush. It may attack one or more main branches or the whole tree. The new sprouts remain yellow and stunted. The number of internodes in them is decreased; but it still remains large enough to give a compact bushy appearance to the sprouts. The internal structure of these branches undergoes considerable change. The cambium, the secondary xylem and the secondary phloem disintegrate, and their cell walls are seen to fuse. The xylem and the phloem are reduced in quantity. The amount of chlorophyll is lessened. The epidermis increases to give a better protection to the suffering branches. Multiple sprouts arise just below the dead parts of the branches. The death of the branches is steady and gradual. The leaf undergoes a reduction both in its length and in its breadth. The leaf-factor increases, indicating a narrow longish shape of the leaves. The chlorophyll grains in the affected leaves are very few and they occupy a narrow region. The fruits are stained and mostly drop under-developed. The skin of the fruits which persist becomes warty, and the juice in such fruits is scanty and insipid. With these symptoms progressing rapidly the whole tree dies in about four years.

* * * * * *

Plate No. 3.—Santra fruit from a Die-back affected tree. Note the warty rind.

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CHAPTER II

The Relation of the Soil and Soil-condition to Die-back

As pointed out in the preceding chapter it has been generally observed that the Citrus plant is much more susceptible to Die-back on some soils than on others. It was accordingly decided to compare the behaviour of Citrus plants on the following five types of soil :—

(1) Black. (3) River. (5) Compost.
(2) Shadu. (4) Sand.

The characteristic features of these soils may be summarised as follows :—

Table No. 16

Name of Soil	Chemical Characteristics			Physical Characteristics					P. H. Value	Maximum water holding capacity in percentage*	General Characteristics
	Percentage of			Percentage of							
	Stones	Nitrogen	Lime	Fine silt	Medium silt	Coarse silt	Fine sand	Coarse sand			
Black ..	7·5	0·06	3·80	34·65	7·91	26·50	24·21	6·73	8·3	77·82	A heavy sticky Soil derived from Trap rock.
Shadu ..	19·7	0·005	15·35	30·69	6·33	20·81	20·74	21·43	8·8	70·8	A whitish limy Soil.
River ..	..	0·11	0·90	32·12	7·20	24·69	30·85	5·54	7·8	68·7	A red alluvial Soil.
Sand ..	Nil	..	..	..	..	..	..	..	..	..	A cleanly washed gravel.
Compost ..	..	0·14	..	..	..	..	..	..	7·8	..	A mixture in equal parts of river soil, sand, and leaf-mould.

* These figures were kindly supplied by the Soil Physicist to the Government of Bombay. The other figures in this table were obtained by the kindness of the Agricultural Chemist to the Government of Bombay.

The Black and Shadu soils give an alkaline reaction while that of the others is neutral.

Tubs of the following dimensions and description were filled with each of these soils :—

Diameter in inches	.. ..	24″
Depth in inches	.. ..	15″
Quantity of soil	.. ..	2·4 cubic feet.
Number of drainage holes	.. ..	3

At the bottom of each tub a layer of potsherds and dried leaves to a depth of 10 cms. was arranged in order to ensure good drainage. Six tubs were allotted to each soil and thus there were 30 tubs in all.

In each tub one orange plant was planted. These were Santra plants (*Citrus aurantium*) or loose skinned oranges. All were budded on Jamburi stock (*Citrus medica*, variety *limonum*).

The marginal statement summarizes the life-history of the plants previous to the date of planting in the tubs from which it will be seen that the plants were aged about 10 months from the date of budding, and the average height was 52 cms. The photograph (Plate No. 4) indicates the lay-out of the experiment.

Operation.	Date.
Sowing seed ..	15th June 1923.
Budding ..	17th October 1924.
Planting in tubs ..	9th August 1925.

Subsequent to planting the only after-treatments given to these tubs were watering and mulching. All fallen leaves were removed to avoid the addition of humus.

The plants had shed their leaves within a week of planting, and after the lapse of another month the plants were well established and making new growth. As a consequence of the shock of transplantation the tips of terminal branches of a few plants dried up but the latter soon recovered.

The onset of the disease, Die-back, became apparent after about four months from the date of transplantation in certain tubs. By this time four plants out of six in the Shadu and Sand soils began to show a pale yellow colour in the leaves, and after the lapse of another two months the foliage of all the six plants in each of these soils had developed a marked yellow colour. By this time the disturbance in normal development was obvious.

When examined in May 1926 (10 months after planting) the condition of the plants was as follows :—

Shadu Soil.—The terminal branches of the plants were drying.

A little later the same condition was observed in the plants in the Sand soil.

Subsequently there was progressive deterioration in the condition of the plants in these two soils. All the leaves assumed a deep yellow colour and many of the branches dried. New growth was sparing, and the plants in the sand just managed to remain alive.

In the River soil and in the Compost the plants remained throughout in excellent health, and growth was vigorous.

Plate No. 4.—A general view of the lay-out of the experimental cultures of citrus plants in different soils.

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The plants in the Black soil behaved in an intermediate manner, and growth was poor.

A year later, May 1927, it was observed that the growth of all the plants in each of the soils except compost, had apparently sustained a check as they had lost their former healthy appearance.

The following table and graph illustrate the vegetative power of the plants in the different soils at the flush periods of 1927 :—

TABLE No. 17.

Soil.	No. of sprouts per plant put forth in the flush of February-March 1927.	No. of sprouts put forth per plant in the flush of June-July 1927.	No. of sprouts per plant put forth in the flush of September-October 1927.
1. Black	116	83	55
2. Shadu	83	76	10
3. River	122	88	75
4. Sand	55	27	11
5. Compost	226	141	136

Note.—See Figure No. 7.

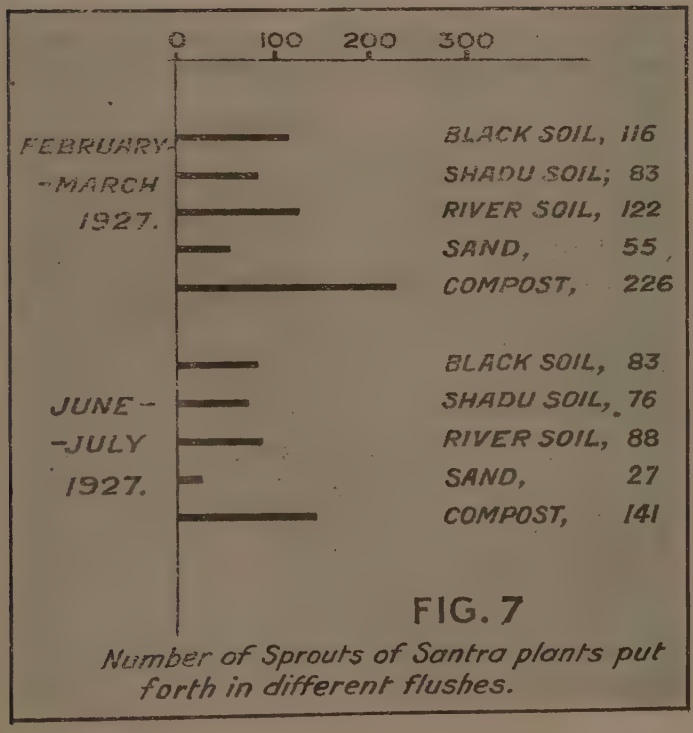

FIG. 7

Number of Sprouts of Santra plants put forth in different flushes.

If we take the figures of the compost plot as representing plants of normal health we can gauge the loss of vitality in the plants in the other soils and the decline appears to be definitely progressive.

Another significant fact was the location on the plant whence the new sprouts took place. Normally new growth is concentrated in the upper regions of the plant. The marginally noted figures show the June-July sprouts analysed according to position on the plant. Those sprouts arising from the lower regions approximated to water-sprouts being deep green in colour and hence this phenomenon supports the conclusion that there has been a definite disturbance to the equilibrium of the plants. It would seem that the stimulus to growth caused by the Monsoon could only be responded to in a partial manner by the tops of the plants, and the surplus sap was directed to the dormant buds lower down. This kind of growth has been associated by many investigators including Floyd (6) and Fawcett (5) with Die-back disease. They regard it as one of the secondary symptoms of this disease, appearing immediately before the disease itself appears.

TABLE No. 18.

Soil.	Number of new sprouts in June-July 1927 flush.	Percentage of sprouts arising from dormant buds in the lower region of the plant.
Black ..	83	13
Shadu ..	76	14
River ..	88	7
Sand ..	27	41
Compost ..	141	1·4

Note—See Figure No. 8.

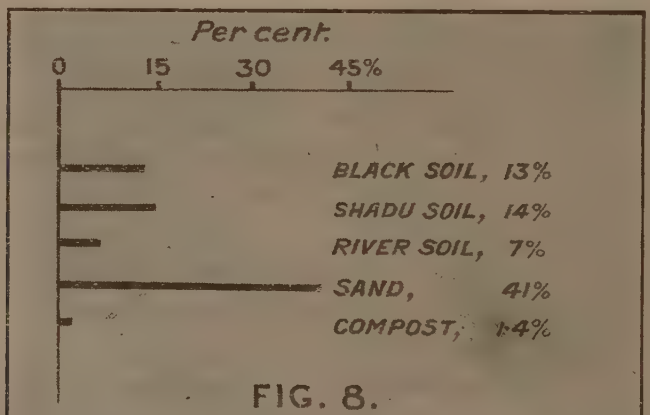

FIG. 8.

Percentage of Sprouts arising from the dormant buds on the thicker stems, in different soils on the eve of the appearance of Die-back.

Associated with this loss of vitality there has also been a progressive deterioration in the condition of the foliage of the plants as may be gathered from the following statement and diagram :—

TABLE No. 19.

Name of soil.	Number of leaves per plant.					
	April 1927.			Late July 1927.		
	Total No. of leaves per plant.	No. of yellow leaves per plant.	Per cent. of yellow leaves.	Total No. of leaves per plant.	No. of yellow leaves per plant.	Per cent. of yellow leaves.
1. Black ..	1,053	15	1·5	1,026	1,026	100
2. Shadu ..	936	413	44·0	979	979	100
3. River ..	1,558	20	1·3	1,660	1,660	100
4. Sand ..	422	422	100·0	496	496	100
5. Compost ..	2,250	20	1·0	2,571	51	2·0

Note.—See Figure No. 9.

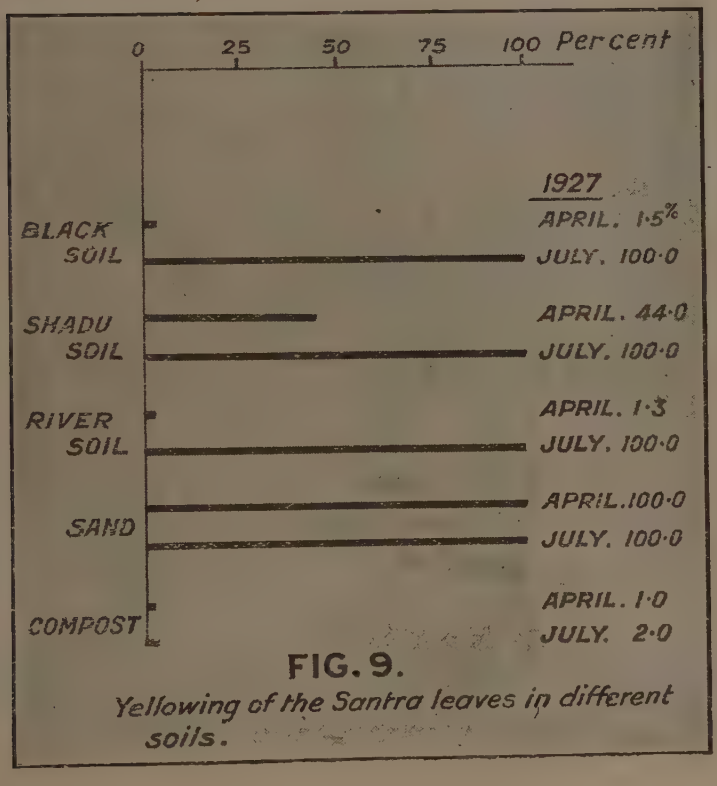

FIG. 9.

Yellowing of the Santra leaves in different soils.

Whereas in April 1927 the percentage of yellow leaves was inappreciable on the black and river soils it had reached 100 per cent. in July when foliage normally responds to the stimulus of the Rains. This condition had already developed in April 1927 in the case of the sand soil. The plants in the Shadu soil occupied an intermediate condition showing 44 per cent. of yellow leaves in April 1927 and 100 per cent. in July 1927. A normal condition characterized the plants in the Compost soil in July 1927, and hence the yellowing of the foliage of the plants in the other soils must be ascribed to the presence of an adverse factor in the environment.

At this stage it will be useful to describe more fully the condition of the plants in April 1927 just before the general decline set in. The following table records certain important measurements from which it will be seen that up to April 1927 growth as measured by girth and height and spread, was approximately normal in the case of the plants growing in black and river soils if we take the plants in the compost soil as representing normality. In the black soil the plants have shown a tendency to height rather than spread. The plants in the Shadu soil were definitely sub-normal, while the plants in the sand were poorly developed.

By this time the power for throwing out new-growth appears to have already received a severe check on all the soils. Generally the plants have behaved in accordance with local experience, *vide* page 6 in which Rahuri experience is set forth.

TABLE No. 20.

Name of soil.	Girth of stock in cms.	Maximum height in cms.	Maximum spread in cms.	Total number of sprouts per plant.
1. Black	9·4	151	96	194
2. Shadu	8·1	135	87	152
3. River	10·9	152	103	292
4. Sand	6·2	84	51	110
5. Compost	10·0	143	112	415

Note.—See Figure Nos. 10, 11, 12 and 13.

Figures in this table are averages of six plants in each case.

Plate No. 5.—Relative growth of Santra plants in different soils.

From left to right.—1. Black soil. 2. Shadu soil. 3. River soil. 4. Sand. 5. Compost. 6. Water-logged culture. 7. Stone-lined culture.

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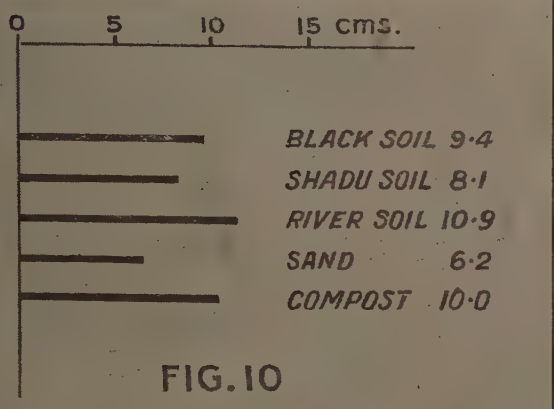

FIG. 10

The girth of the stock of Santra plants under different soil conditions.

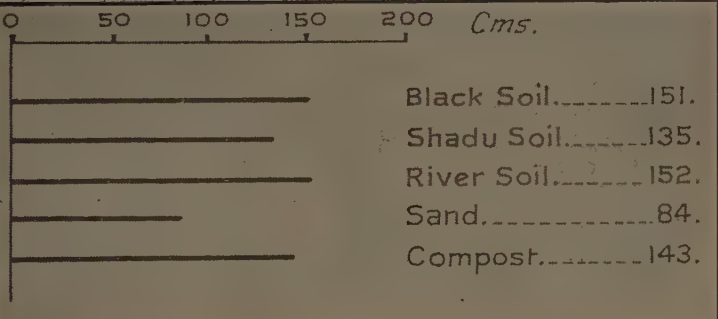

FIG. II

The maximum height of Santra plants under different soil conditions.

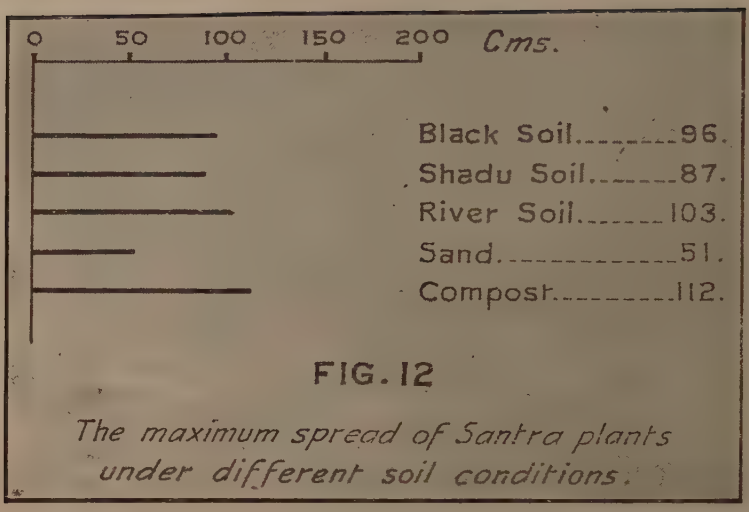

FIG. 12

The maximum spread of Santra plants under different soil conditions.

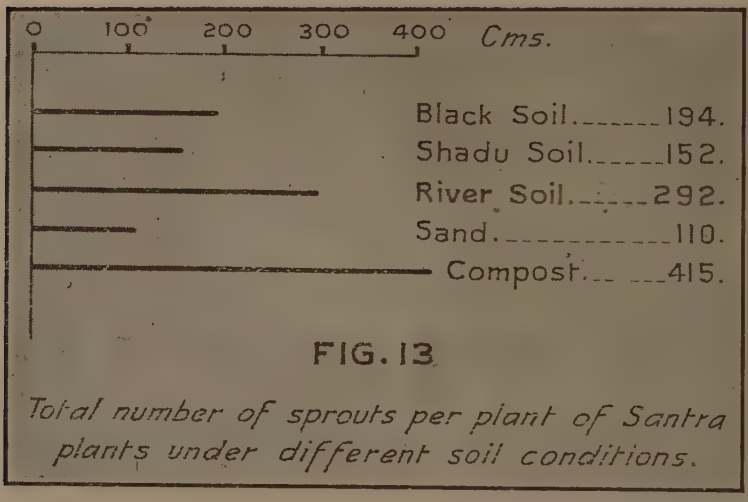

FIG. 13

Total number of sprouts per plant of Santra plants under different soil conditions.

The cause of this deterioration of the plants would appear to be soil exhaustion due to the quantity of soil in the tubs being insufficient to maintain the enlarged plants in a state of normal health. In the later stages, however, it is probable that loss of soil-condition resulting in lack of sufficient aeration, played part in some soils, as by that time the soils in the tubs had become very compact. This, however, could hardly be the case in the sand soil.

Accordingly it was decided to test the degree of exhaustion of the three principal soils in a practical manner. A number of shallow earthen pots were filled with soil taken from the tubs.

Plate No. 6.—The growth of Jowar seedlings in soils exhausted by Santra plants growing in them, compared with that of jowar seedlings in soils fresh from the fields.

From left to right—

1. Jowar seedlings grown in exhausted river soil.
2. Jowar seedlings grown in fresh river soils.
3. Jowar seedlings grown in exhausted shadu soil.
4. Jowar seedlings grown in fresh shadu soil.
5. Jowar seedlings grown in exhausted black soil.
6. Jowar seedlings grown in fresh black soil.

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Plate No. 7.—The development of the roots of Santra plants in the different soils.

1. Plant from black soil. **2.** Plant from shadu soil. **3.** Plant from river soil. **4.** Plant from sand. **5.** Plant from compost.

[*To face page 29*

In each of these pots 200 Jowar (Sorghum) seeds were sown on the 13th January 1928. A comparative series of pots were prepared with the same soils taken fresh from their respective sources.

The growth of the jowar seedlings was remarkably superior in the control pots than in the pots containing the soil obtained from the tubs, as will be gathered from the following statement which records the average heights of the plants on the 24th February 1928 :—

TABLE No. 21.

Name of soil.	Average height of jowar seedlings in soils from	
	the Santra tubs.	the fields.
	Cms.	Cms.
1. Black	12	13
2. Shadu	10	16
3. River	14	22

This test suggests that soil exhaustion may be an important factor in causing the disease in the shadu and river soils, but it does not seem to account for the disease in the plants grown upon the black soil. It is, however, possible that the excess of lime accounts for the disease in the shadu soil.

It was thought that the root systems of the plants grown in these soils might prove suggestive. It was found that the development of the roots behaved differently in the different soils. It seems permissible to assume that a good root system will become developed in the absence of any inhibiting factor or factors. It was found that the root system developed in the compost soil was excellent, and it was noticeable how strong and thick were the side roots while the branching was free and extensive but individual roots were not long. This type of root system would appear to be what may be expected under optimum conditions, indicating that aeration is excellent.

In the black soil the root system was found to be markedly different. The tap root was deep but the general system was thin and superficial, thus resulting in a restricted feeding space. This poor development would seem to be associated with inadequate aeration.

In the shadu soil the root system was superior to that in the black and sand soils, and the fibrous roots were numerous.

In this soil die-back does not appear to be due mainly to a badly developed root system.

In the River soil the root system was good.

In the Sand soil the root system was fairly good.

Hence it would seem that the root system gives a clue to die-back in the case of black soil, but hardly accounts for it in the other soils under observation.

Soil-conditions calculated to induce die-back.

Two subsidiary tub-experiments were conducted with the object of inducing die-back.

One was designed so as to create a water-logged condition of the soil.

The other was designed so as to assimilate hard-pan conditions in the soil.

Both experiments which were conducted with river-soil in tubs, were quite successful as may be gathered from the following tabular statements which give quantitatively the extent of damage to normal growth done by these inhibiting factors.

Effects of Water-logging.

TABLE No. 22.

Name of culture.	Girth of stock in cms.	Maximum height in cms.	Maximum spread in cms.	Total number of sprouts.	Remarks.
1. Plants watered once a month.	7·85	103	62	174	Average of two plants.
2. Control	10·5	151	103	292	Average of six plants.

Effect of hard-pan.

TABLE No. 23.

Name of culture.	Girth of stock in cms.	Maximum height in cms.	Maximum spread in cms.	No. of sprouts per plant.	Remarks.
1. Stone lined ..	8·55	144	80	228	Average of two plants.
2. Control	10·50	151	103	292	Average of six plants.

In both cases the disease appeared to be traceable to root-trouble. In the water-logged plants the roots simply rotted while in the case of the plants grown under hard-pan conditions, an examination of the roots showed that a large number of the roots had come in contact with the stone-lining on the sides and bottom of the tubs, where they had become flattened and compressed. An examination under the miscroscope indicated that the internal structure of the roots had sustained damage from pressure. Hence the roots could no longer function properly and thus the plants developed Die-back.

From the foregoing investigations it appears that certain broad conclusions can be drawn with regard to the causes of die-back.

It would seem that certain soils and soil-conditions predispose the plant to this disease such as

(1) soils containing an excess of lime.
(2) soils deficient in plant food.
(3) soils deficient in aeration.
(4) soils having a hard substratum.
(5) soils in a water-logged condition.

Hence the precautions to be taken against this disease appear to be such measures as will eliminate or minimize the defective conditions just described.

Similarly an orchard suffering from die-back can be restored to health by adopting suitable measures.

In the following chapter it is proposed to give an account of successful treatment of orchards for die-back disease.

CHAPTER III

Examples of Successful Treatment of Die-back Disease

Pot-Experiments show that leaf-mould is an effective treatment for Mosambi trees suffering from Die-back, whereas soil taken from a lucerne plot has shown little effect. The following statement summarises the results of an experiment with these materials :—

Table No. 24.

Treatment	Girth		Maximum height		Maximum spread		Total number of sprouts	
	January 1927	July 1927	January 1927	July 1927	January 1927	July 1927	Jan. 1927	July 1927
	cms.	cms.	cms.	cms.	cms.	cms.		
1. Lucerne-field-soil ..	6·9	7·1	79	79	51	49	28	45
2. Leaf-mould ..	7·5	8·7	84	117	67	70	25	98
3. Control	6·9	7·0	79	78	55	48	27	38

Note.—These figures are average of two plants in each case.

The plants experimented with were growing in shadu soil in tubs and were suffering badly from Die-back and were very stunted in growth. The quantity of lucerne-field-soil applied per tub was 10 lbs. and although this treatment stimulated a flush on the plants within a fortnight still there was no appreciable growth. The quantity of leaf-mould was also 10 lbs., and this was well rotted ; in this case also there was a flush within a fortnight, and the foliage became deep green. Health was restored while the plants in the control tubs just held on to life. An examination of the roots showed that there were 120,190 root-tips in the recovered plant and 67,247 in the control plant.

Plate No. 8.—Effect of lucerne-field soil and leaf-mould on die-back affected Mosambi plants, growing in shadu soil. Note the complete recovery of the plant when treated with leaf-mould (in the centre).

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Plate No. 9.—An open trench taken in a Mosambi garden which was severely affected with Die-back, at Kolhar. The percolation water running in the trench as well as the rank growth of weeds on its sides may be noted.

[*To face page 33*

At Kolhar in the Ahmednagar District Mr. Govindrao Kulkarni planted an orchard of Mosambis on a piece of deep heavy black soil in the midst of copiously watered sugarcane fields. The land had a surface slope from north-east to south-west but there was no drainage system to carry off the excess water. When the trees were only six years old Die-back disease had made its appearance, and in the following year the disease had developed to a considerable extent, and the yield had seriously diminished while the disease was rapidly increasing. The owner was at a loss to know what to do. He was accordingly advised to drain the orchard. Long trenches were dug around the borders of the orchard, two feet wide and four feet deep. These trenches surrounded three sides of the orchard and they discharged into a neighbouring nalla. Although no water was allowed to enter these trenches from the surface, water was found in them all the year round. The sides of the trenches soon became overgrown with hariali (*Cynodon dactylon*) and thus the danger of them falling in became removed. The following figures indicate the details :—

Length of trenches	..	1,500 ft.
Width of trenches	..	2 ft.
Depth of trenches	..	4 ft.
Total earthwork	..	12,000 c.ft.
Total cost	..	90 Rs.
Total trees in orchard	..	475
Cost per tree	..	3 As.

The annual clearance of these trenches has cost Rs. 50 per annum or 2 annas per tree.

Side by side with this drainage the orchard received the following attention. All the dead wood was removed and a dose of manure was given in the following manner :—

January 1925	..	100 lbs. of cattle manure per tree.
March 1925	..	1 lb. of bone meal per tree.
June 1925	..	4 lbs. of castor cake per tree.

This treatment proved completely successful, and in a period of eighteen months the plantation came to heavy bearing.

Similarly good results have been obtained in the garden of the Public Works Department Inspection bungalow at Deolali, Ahmednagar district, by Professor D. L. Sahasrabudhe (17). The soil of the garden was sticky and badly ærated. In this garden Die-back appeared in 1921-1922, and by 1924-1925, it had increased to such an extent that it was feared the plants would die off in the course of a few years. As a remedy against Die-back, it was advised to open trenches 3 feet wide and 3 feet deep midway between the rows of trees in the orchard, and fill the bottom to a depth of nine inches with bricks, stones, and branches. The soil to which was added a little manure was then replaced. Great

improvement in the plants on the trenched area was observed ten months after making the trenches, while the plants on the control area were going from bad to worse.

A carefully conducted experiment in the Ganeshkhind Botanical Gardens, Kirkee, has yielded interesting results.

In November 1925, this plantation contained 235 trees, five years old, of which 4 trees showed the symptoms of Die-back. A year later, November 1926, there were 70 trees affected. The soil of this orchard was black and sticky, and more than five feet deep. The orchard is commanded by canal water, but the site stands high and there was no water-logging.

It was decided to treat 110 trees which stood in eight consecutive rows in the centre of the plantation. Of these 110 trees, 42 were affected with Die-back and 68 were healthy.

The treatment consisted of digging trenches 3 feet deep and 2 feet wide exactly midway between two rows of trees which stood 20 feet apart. These trenches were left open for four months in the fair season. They were then filled in with brushwood material to a depth of 2 feet from the bottom and soil above. These drains discharged into a common drain which discharged into an adjoining river. All dead-wood was removed, and other treatments except manuring were common to all the trees.

The manurial treatments were as follows:—

TABLE No. 25.

Name of manure	Quantity of manure per tree in lbs	Trenches on sides	Number of trees treated			Percentage of recoveries in nine months
			Healthy	Attacked	Total	
Sulphate of Ammonia ..	1	*Nil*	19	8	27	63
Lucernefield soil ..	100	*Nil*	10	3	13	*Nil.*
Lucernefield soil ..	100	One side	6	7	13	29
Nil	....	Both sides	14	14	28	37
Leaf-mould	50	One side	8	6	14	33
Leaf-mould	50	*Nil*	9	4	13	25
Control	*Nil*	*Nil*	..	2	2	*Nil.*

Plate No. 10.—A Mosambi orchard revived from Die-back and in a profusely bearing condition as a result of drainage trenches, as shown in Plate No. 9.

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The manures were all mixed well with the soil. The sulphate of ammonia was applied in two equal dozes at an interval of three months.

Below are summarised the measurements, etc., of these trees at the beginning of the experiment and again after a lapse of nine months. It may, however, be stated that out of the 42 affected trees standing scattered throughout the area, which have been treated, 15 have recovered completely while the 27 others are showing a slight yellowing only. It is also important to record that none of the 68 healthy trees which have received treatment have become attacked by the disease, whereas in the untreated area the number of affected trees has increased from 28 to 52 out of a total of 125. The degree of attack has also greatly increased in the case of the 28 trees.

TABLE No. 26.

Height of Santra trees.

Date of observation	Treatment						
	Sulphate of Ammonia	Lucerne-field soil	Lucerne soil *plus* trench on one side	Trenches on two sides	Trench on one side *plus* leaf-mould	Leaf-mould alone	Control
	Feet	Feet	Feet	Feet	Feet	Feet	Feet
January 1927 ..	7·4	10·6	9·6	9·4	10·7	10·6	9·5
August 1927 ..	8·25	10·8	10·2	9·75	11·42	11·3	9·8
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Increase per cent ..	11	2	6	4	7	7	3

Note.—See Figure No. 14.

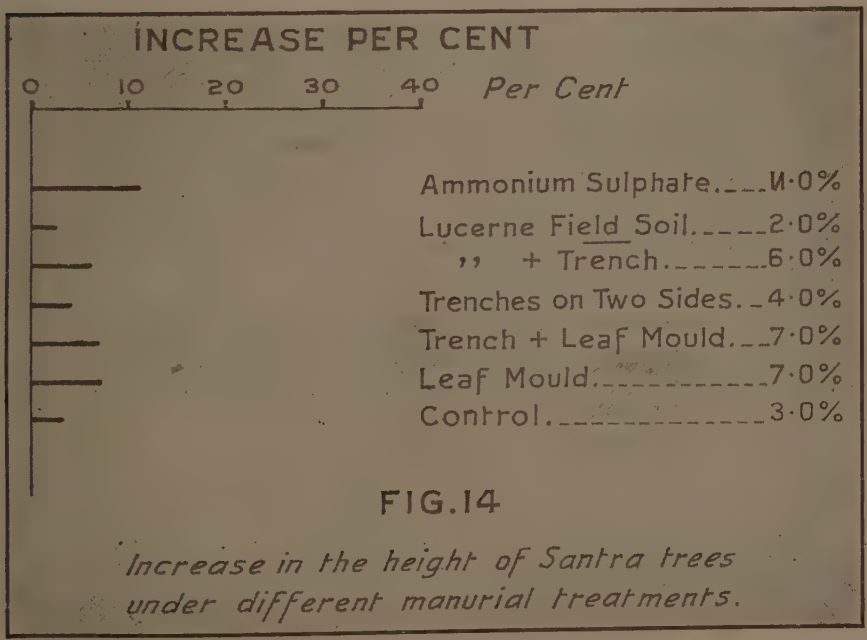

FIG. 14

Increase in the height of Santra trees under different manurial treatments.

Table No. 27.

Spread of Santra trees.

Date of observation	Treatment						
	Sulphate of Ammonia	Lucerne-field soil	Lucerne soil *plus* trench on one side	Trenches on two sides	Trench on one side *plus* leaf-mould	Leaf-mould alone	Control
	Feet	Feet	Feet	Feet	Feet	Feet	Feet
January 1927 ..	4·7	7·9	6·44	6·4	7·8	7·46	5·6
August 1927 ..	5·8	8·7	7·10	7·4	8·9	8·50	5·6
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Increase on square basis ..	52	21	21	34	31	30	*Nil.*

Note.—See Figure No. 15.

The figures are all averages of the number of trees treated under each head.

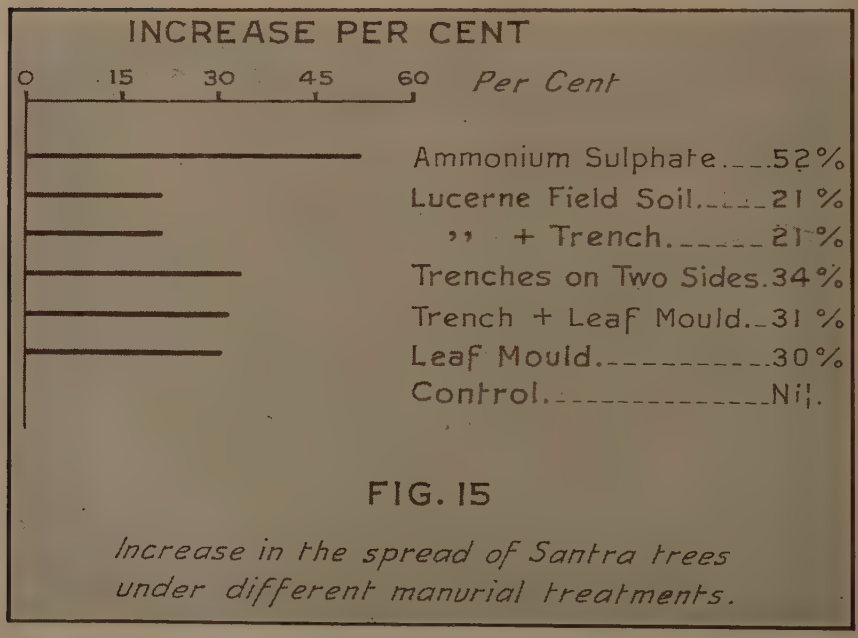

FIG. 15

Increase in the spread of Santra trees under different manurial treatments.

TABLE No. 28.

Girth of Santra trees.

Date of Observation	Treatment						
	Sulphate of ammonia	Lucerne-field soil	Lucerne soil and trench on one side	Trench on two sides	Trench on one side and leaf-mould	Leaf-mould	Control
	Feet	Feet	Feet	Feet	Feet	Feet	Feet
January 1927 ..	0·76	1·24	1·03	1·00	1·23	1·2	0·88
August 1927 ..	0·87	1·30	1·10	1·10	1·45	1·4	0·90
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Increase ..	14	5	7	10	18	17	2·3

Note.—See Figure No. 16.
These figures are the averages of the number of trees treated under each head, as shown in Table No. 25.

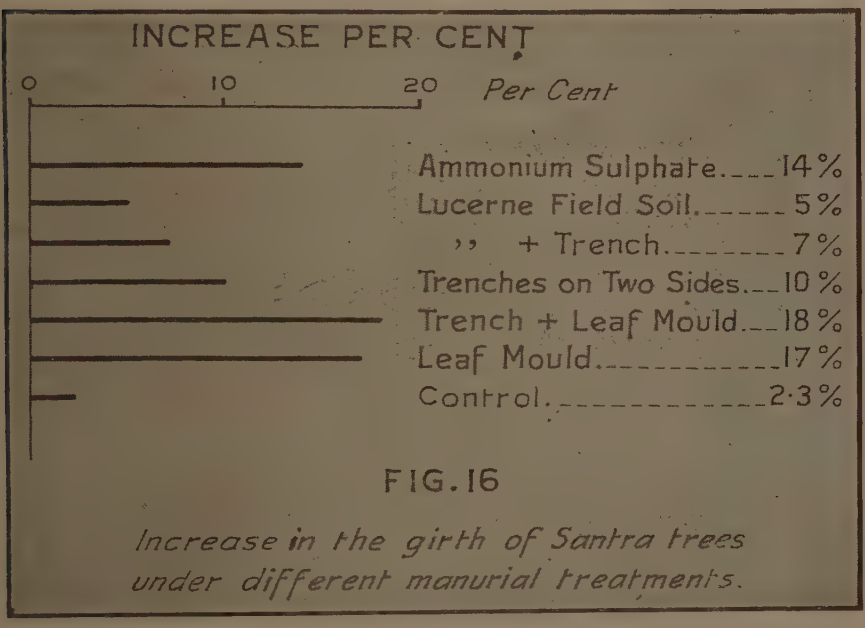

FIG. 16

Increase in the girth of Santra trees under different manurial treatments.

1. The height of the trees shows an increase all over, but except in the case of the trees treated with sulphate of ammonia and leaf-mould, the increase is not considerable.

2. The spread of the trees under the different treatments, shows a great variation. This factor is somewhat more complicated than the others, because its development is in all directions. The records have been made of the maximum diameter of the trees but a correct idea of the spread of the trees will be obtained by raising these figures to their squares. The percentages have, therefore, been calculated on the squares of the two observations.

Trees treated with sulphate of ammonia show the greatest increased spread of 52 per cent., while those treated with trenches on two sides and leaf-mould show increases of 34 per cent. and 30 per cent. respectively. Trees under the other treatments are much lower in increase of spread, being somewhere about 20 per cent. Even then there is definitely an increase in the spread of trees under the various

treatments, when compared with the spread of the control trees, which is nil.

3. The increase in girth of the trunk is not much greater than that of the control trees in the case of trees treated with the lucerne-field soil. Trees which had trenches on two sides show an increase of 10 per cent. while those treated with sulphate of ammonia and leaf-mould are far superior with increases of 14 per cent. and 17 per cent., respectively.

So much for the factors considered separately. Trees have responded well to sulphate of ammonia, leaf-mould, and trenches on two sides in all cases. Lucerne-field soil does not seem to exercise any considerable influence. Sulphate of ammonia has yielded the best results, while leaf-mould and trenching are more or less similar. The cumulative effect on the trees under the treatments can be brought out better by taking into account, the increase in spread as well as in height combined. This can be done by comparing the volumes of the trees, as obtained by multiplying their heights with the square of their spreads, and calculating percentages on this basis.

The figures stand as follows :—

TABLE No. 29.

Statement showing the increase in the volumes of the Santra trees.

Treatment	Sulphate of ammonia	Lucerne-field soil	Lucerne-soil *plus* trench on one side	Trenches on two sides	Trench on one side *plus* leaf-mould	Leaf-mould alone	Control
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Percentage increase of volume ..	70	23	28	38	38	38	3

Note.—See Figure No. 17.
The figures are averages as in the previous cases.

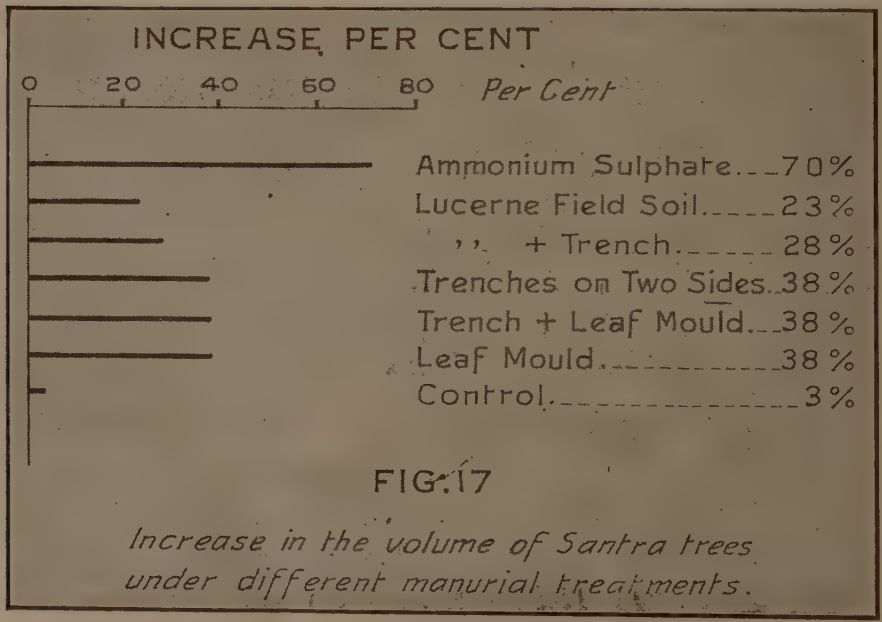

FIG. 17

Increase in the volume of Santra trees under different manurial treatments.

From the above table it is clear that sulphate of ammonia has induced the greatest growth while trenches on two sides and leaf-mould equal one another in their effect. The other treatments are not so effective.

In order to obtain a more definite idea of the effects of these different treatments, a certain number of representative trees were selected from each lot and their branches were counted and recorded on both the occasions. The figures stand as below :—

TABLE No. 30.

Number of branches of Santra trees.

Date of observation	Sulphate of ammonia	Lucerne field soil	Lucerne soil *plus* trench	Trenches on both sides	Trench *plus* leaf-mould	Leaf-mould alone	Control
January 1927 ..	1,675	3,393	2,634	2,078	2,988	3,405	1,859
August 1927 ..	2,900	5,030	4,141	3,648	4,754	5,331	1,915
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Increase per cent. ..	73	48	57	76	59	57	3
No. of trees ..	6	4	4	5	3	3	2

Note.—The figures in the foregoing table are the averages of the number of trees mentioned in the last line of it.

See Figure No. 18.

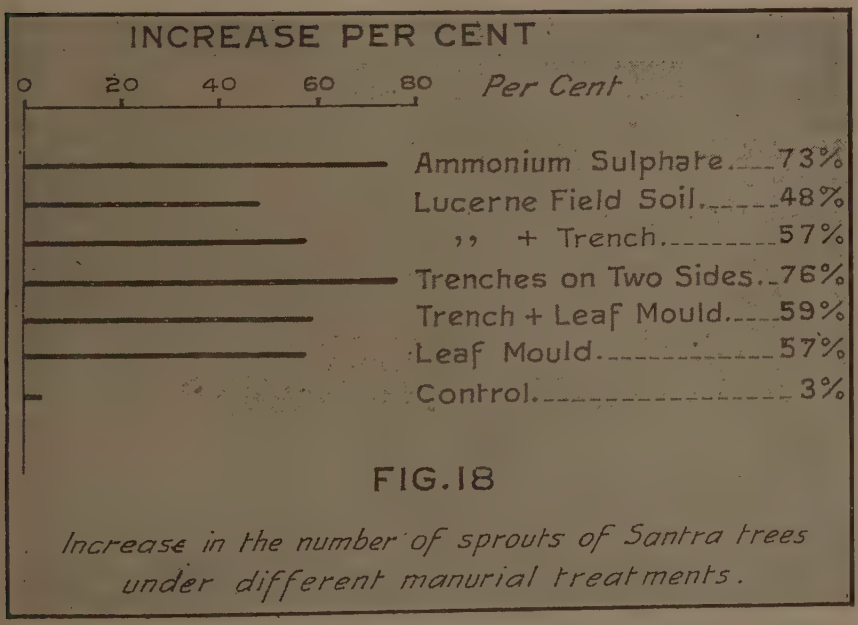

FIG. 18

Increase in the number of sprouts of Santra trees under different manurial treatments.

Sulphate of ammonia and trenches have thus induced the greatest number of sprouts, while leaf-mould and lucerne-field soil have been less effective.

To sum up, the treatments have all been curative as well as preventive, irrespective of the degrees to which the trees have responded to them. Sulphate of ammonia has induced the best growth of the trees and has helped diseased trees to recover to the greatest extent. Its quick availability to the trees is probably what has placed it at the top of the list. Trenching comes next. It induces the recovery of affected trees to a great extent and stimulates profuse growth. It improves soil æration and effects good drainage. Leaf-mould stands third in its effect. The effect of leaf-mould may be rather slow. It is two-fold in that it loosens the soil and adds to its fertility. Lucerne-field soil does not deserve recommendation.

The cost of these various treatments will now be considered. Taking one acre to contain 200 citrus trees at a distance of 15 feet apart, the cost of the materials required is as follows :—

TABLE No. 31.

Name of material	Quantity required per acre	Price	Cost per treatment	Cost on four years' basis
			Rs.	Rs.
Sulphate of ammonia ..	200 lbs.	Rs. 20 per bag of 2 cwt.	18	72
Leaf-mould ..	10,000 lbs.	Rs. 3 per 500 lbs. ..	60	120
Lucerne-field soil ..	20,000 lbs.	Rs. 2 per 1,000 lbs...	40	80
Trenching on two sides of trees ..	18,000 cubic feet.	Re. 1 per 100 c. ft. for digging ..	180	360
		Re. 1 per 100 c. ft. for refilling ..	180	

In the manurial figures, the cost of labour is not taken into consideration, because not much extra labour is required for the application of the manures as this can be given along with the usual dose of Farm Yard Manure. The cost of trenching is mainly the cost of labour for digging and refilling, and hence in this case the question of labour for application does not arise at all. The cost of refilling the trenches includes the cost of brushwood materials required.

Sulphate of ammonia is assumed to be applied every year at the rate of 1 lb. per tree. Leaf-mould is assumed to be applied once in two years, as its effect is more lasting than that of sulphate of ammonia. The figures regarding the cost of applying lucerne-field soil may be ignored as this material has not given encouraging results. The effect of trenching is assumed to last for at least four years. Hence, the cost of the different treatments has been finally calculated on a four years' basis for comparison.

The figures indicate that the cost of trenching is prohibitive. This however, is due to the high rate of rupee one per 100 c. ft. assumed. It should in practice be cheaper, and much might be done in spare time. Economy can be further effected by trenching one side only of the trees, where this is sufficient. Again the trenches may be left open. It is of course necessary only where water-logging or bad æration prevails.

CHAPTER IV

A Study in Stocks with special reference to the Control of Die-back Disease

It has been observed in this Presidency that there are a large number of plants belonging to the Natural Order, *Rutaceae*, which may be suitable for use as stock plants on which to raise the better varieties of citrus, and which may be proof against Die-back. Some of these plants such as Id (*Citrus medica*, variety *limonum*) and Mahalung (*C. medica* proper) belong to the genus of citrus, while others such as Kavat (*Feronia elephantum*) and Bel (*Ægle marmelos*) do not. Most of them are seen growing in the jungles and are never cultivated, while those that belong to the genus of citrus proper, are mostly seen under cultivated conditions. The more important of these plants are given below :—

1. *Belonging to the genus Citrus :*
   - *a.* Jamburi (*Citrus medica*, variety *limonum*).
   - *b.* Mahalung (*Citrus medica*, proper ; citron).
   - *c.* Sour Lemon (*Citrus medica*, variety *acida*).
   - **d. Citrus trifoliatus.*
2. *Belonging to the genus Feronia :*
   - **a. Feronia elephantum* (Kavat).
3. *Belonging to the genus Ægle :*
   - **a. Ægle marmelos* (Bel).

Experiments have been started with all these plants. It has been observed that there are some sub-varieties of Jamburi, which apparently do not vary widely from one another. Three sub-varieties of Jamburi, numbered differently, are included in these trials.

This investigation has been two-sided.

The first object has been to ascertain the vigour of these varieties when grown in shadu soil, which has been prompt in inducing Die-back, as seen in a previous chapter ; and to select those varieties which can stand the shadu soil conditions better than others. These selected varieties will be used later as stock plants in such soils.

The *Second* object has been to find out by actual trials the percentage of success attained in grafting and budding citrus scions on the wild stocks, such as Kavat and Bel.

These experiments have been started only recently, but certain observations so far made are of interest.

1. In the first series, seedlings of five varieties of citrus, including three sub-varieties of Jamburi, were raised in the shadu soil, under uniform conditions. Their growth was recorded from time to time. Their heights were measured and their leaves counted. The varieties

* These are wild plants that are under trial for stock.

show a wide difference in their growth as may be seen from the following figures, collected when the plants were eight months old :—

TABLE No. 32.

Name of variety.	Number of plants under observation.	Height in cms.	Number of leaves.	Colour of leaves.
1. Sour lemon	18	7·3	15	Green ; turning pale after a month.
2. Jamburi *No. 130	41	10·0	15	Green.
3. Jamburi *No. 152	31	10·8	18	Green.
4. Jamburi *No. 112	29	13·5	21	Green.
5. Mahalung	15	13·0	17	Pale green.

*These are the registered numbers of the trees in the plantation, from which the fruits were taken for sowing the seeds.

Note.—See Figures Nos. 19 and 20.

The figures are averages of the number of plants under observation in each group.

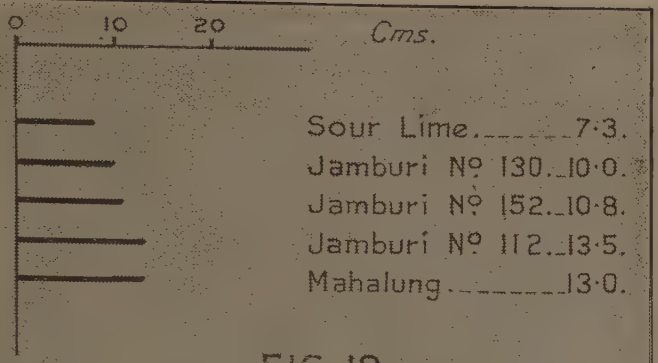

FIG. 19

Height of different stock plants for Citrus, under uniform conditions.

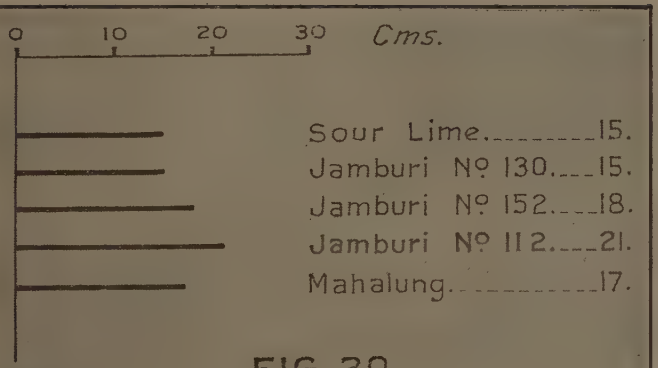

FIG. 20

Total number of leaves put forth by different stock plants for Citrus, under uniform conditions.

The sub-variety of Jamburi No. 112 and Mahalung have far excelled the others in growth. It may be particularly noted that even in the same variety of Jamburi there are types which differ widely in their vigour of growth under given conditions. At present, no proper selection of these sub-varieties has yet been made and they are being used promiscuously as stock plants. If this Jamburi No. 112 continues to maintain its place among the others, as it promises to do, it will be a great asset to the nurserymen as well as to the planters. Observations on these plants continue.

2. The wild plants mentioned in the list above, are seen to grow under the most adverse conditions of environment. They grow well in a deep sticky soil as well as in a shallow light soil, and are also noticed growing in the shadu soil. These plants have, therefore, been first chosen for the trials of grafting and budding.

Forty plants of *Feronia elephantum* were grafted to Santra and Mosambi scions, and they have *all* of them taken. The union was quick and sound. The method of grafting adopted was the simple approach method (inarching). The union takes place in about 50 days, and none of the scions separated from the mother plant, 48 days after grafting, have died. It is an easy operation and success is almost cent per cent. Seedlings become ready for receiving the scions in about two years.

Ægle marmelos has also been tried. This plant is largely found in the country and is propagated by root cuttings and seedlings. The results with these plants are not yet available.

These types seem to be promising. The growth of Santra scions on the Kavat stocks is vigorous as may be seen from Plate No. 11.

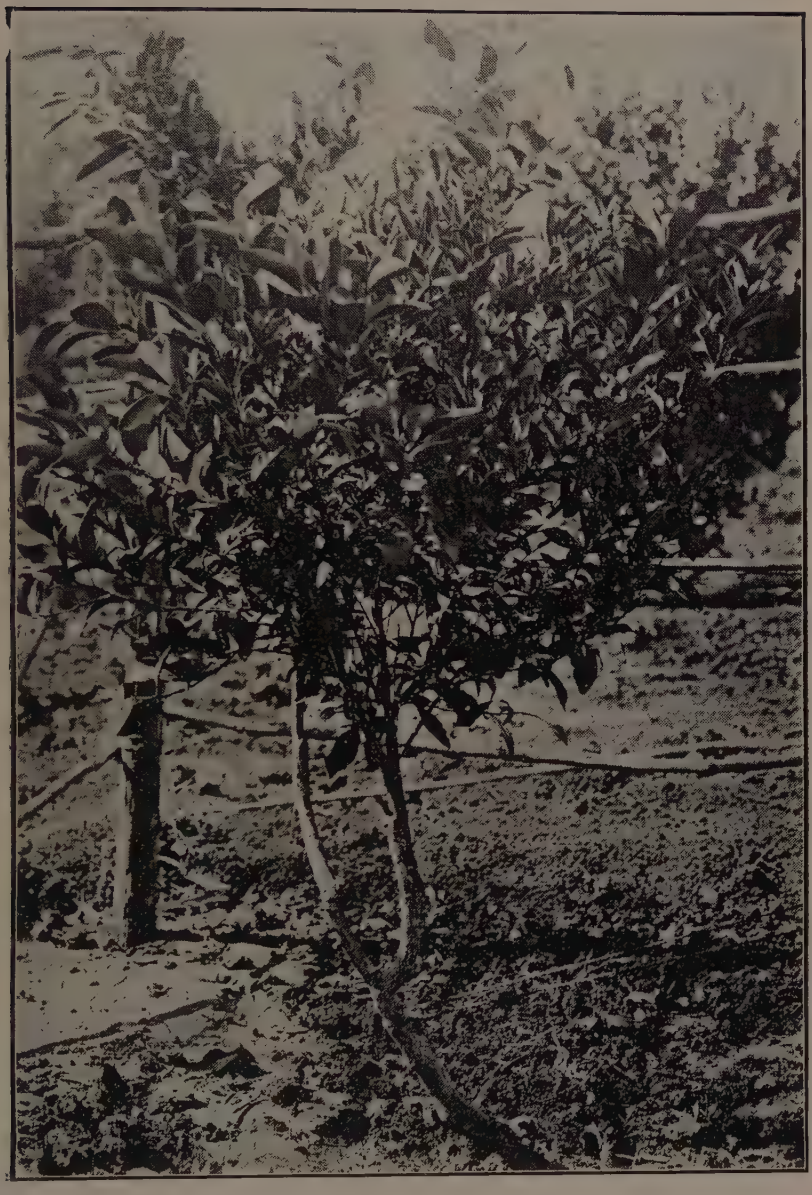

Plate No. 11.—Santra (*Citrus aurantium*, loose skinned) scions growing on Kavat (*Feronia elephantum*) stock. The growth of the scions is of two years after grafting.

[*To face page 44*

Summary

(1) The general features of Die-back disease in the Bombay Presidency are described, and the extent of the damage sustained by Citrus trees is indicated.

(2) The behaviour of the different parts of a diseased tree is described in detail.

(3) The principal types of soil have been studied with reference to Die-back, and the soil-conditions favourable and unfavourable to the disease have been observed.

(4) It has been indicated that several soil-factors acting singly or in combination pre-dispose the Citrus plant to Die-back disease.

(5) Examples of successful treatment for Die-back are described in detail.

(6) Preliminary work in the study of stocks of different *genera* with a view to combat the disease is described.

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